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Introduction

Welcome to another course in the STEP series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Industry, Inc. products more effectively. This course covers **Basics of Control Components**.

Upon completion of Basics of Control Components you will be able to:

- State the purpose and general principles of control components and circuits
- State the difference between manual and automatic control operation
- Identify various symbols which represent control components
- Read a basic line diagram
- Describe the construction and operating principles of manual starters, electromagnetic contactors, and electromagnetic motor starters
- Explain the need for motor overload protection
- Briefly describe the operation of thermal and electronic overload relays
- Describe the advantages of reduced-voltage motor starting
- Describe the types and operating principles of lighting and heating contactors
- Describe the operating principles of control relays
- Summarize the types of NEMA control products offered by Siemens
- Summarize the types of IEC control products offered by Siemens
- Briefly describe the uses for AS-Interface, ASIsafe, IO-Link, and PROFIBUS DP
- Summarize the types of SIRIUS Safety Integrated products offered by Siemens

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products.

You should complete **Basics of Electricity** before attempting **Basics of Control Components**. An understanding of many of the concepts covered in **Basics of Electricity** is required for this course.

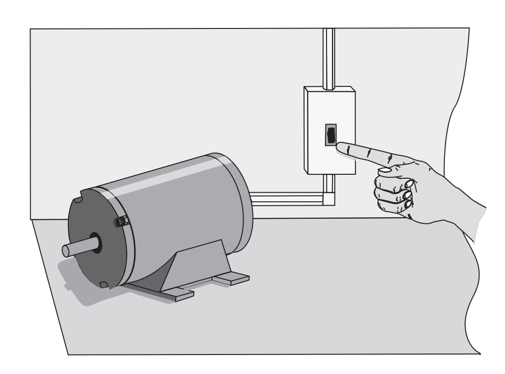
After you have completed this course, if you wish to determine how well you have retained the information covered, you can complete a final exam online as described later in this course. If you pass the exam, you will be given the opportunity to print a certificate of completion.

Control Circuits and Symbols

Control

Control, as it relates to machines and processes, is a broad term that means anything from a simple toggle switch to a complex system.

Control is considered to be **manually operated** when someone must initiate an action for the circuit to operate. For example, someone might have to flip the switch of a manual starter to start and stop a motor.



Although manual operation of machines is still common, many machines are controlled automatically. Frequently there is a combination of manual and automatic control. For example, a machine that is started manually may stop automatically when certain conditions are met.

Control Components

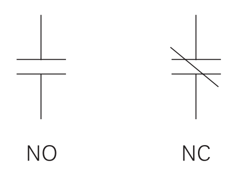
While many control components are used in circuits that involve motors, control components are also used with a variety of other equipment. Various types of control components are used for switching, starting, protecting, detecting, monitoring, communicating, and other functions. The full range of these capabilities is beyond the scope of this course, but examples of devices that perform these types functions are discussed throughout this course.

In some cases, the interaction of these components is dependent only on how they are wired to each other. This is sometimes referred to as **hard-wired logic**. Increasingly, however, these components are wired or networked to a control system, such as a programmable logic controller or variable frequency drive. In such cases, the interaction of the circuit components is dependent both on wiring and the software stored in the controller.

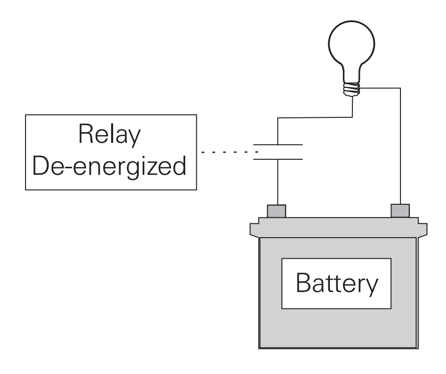
Before discussing specific control devices; however, it is important to understand some basic symbols and diagrams. The symbols and diagrams described in this course are commonly used in North America. Other types of symbols and diagrams are also used.

Contact Symbols

Various devices incorporate contacts to control the flow of current to other control components. When in operation, a contact may be either **open**, a condition which blocks current flow, or closed, a condition which allows current flow. Control logic diagrams, however, cannot show the dynamic operation of contacts. Instead, these diagrams show contacts as either **normally open (NO)** or **normally closed (NC)**.



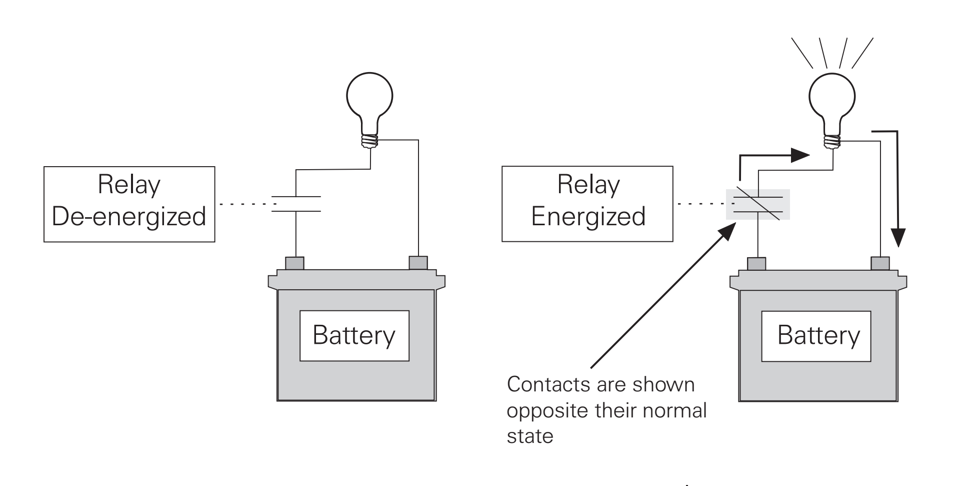
The standard method of showing contacts is to indicate the circuit condition produced when the actuating device is in the **de-energized (off) state**. For example, in the following illustration, the contacts are part of a relay. The contacts are shown as normally open to indicate that, when there is no power applied to the relay's coil, the contacts are open. With the contacts open, there is no current flow to the light.



Symbols on a control logic diagram are usually not shown in their energized (on) state. However, in this course, contacts and switches are sometimes shown in their energized state for explanation purposes. In such cases, the symbol is highlighted.

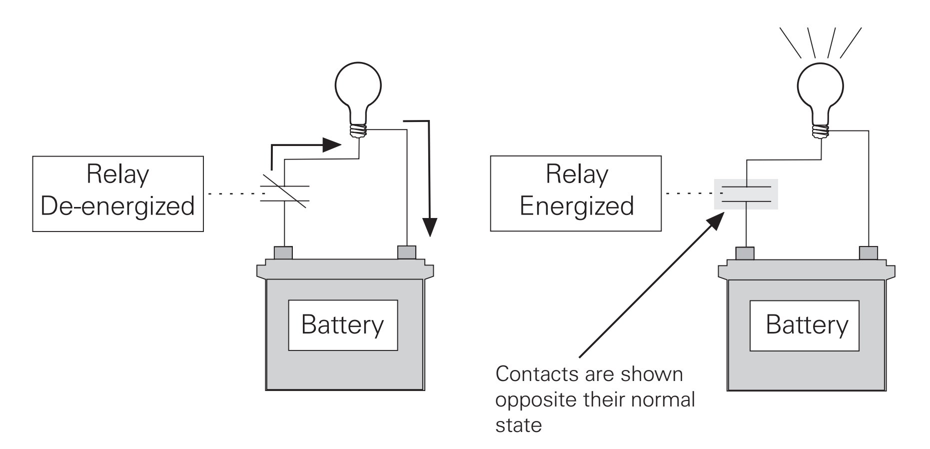
Normally Open Contact Example

For example, in the following illustration, the circuit is first shown in the de-energized state, and the normally open contacts are not highlighted. When the relay energizes, the contacts close, completing the path for current and illuminating the light. The contacts are then shown as highlighted to indicate that they are not not their **normal** state. *Note: This is not a standard symbol.*



Normally Closed Contact Example

In the following illustration, when the relay is de-energized, the normally closed contacts are shown as closed and are not highlighted. A complete path of current exists at this time, and the light is on. When the relay is energized, the contacts open, turning the light off.



Switch Symbols

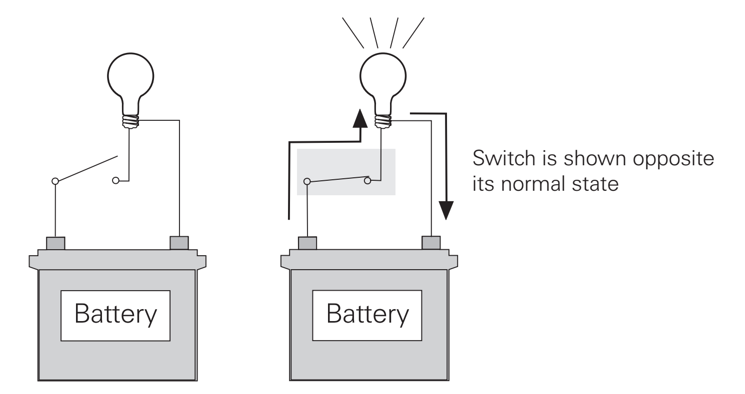
Various types of **switches** are also used in control circuits. Like the contacts just discussed, switches can also be normally open or normally closed and require another device or action to change their state. In the case of a manual switch, someone must change the position of the switch. A switch is considered to be in its normal state when it has not been acted upon.

Switch symbols, like the ones shown in the following illustration, are also used to indicate an open or closed path of current flow. Variations of these symbols are used to represent a number of different switch types.



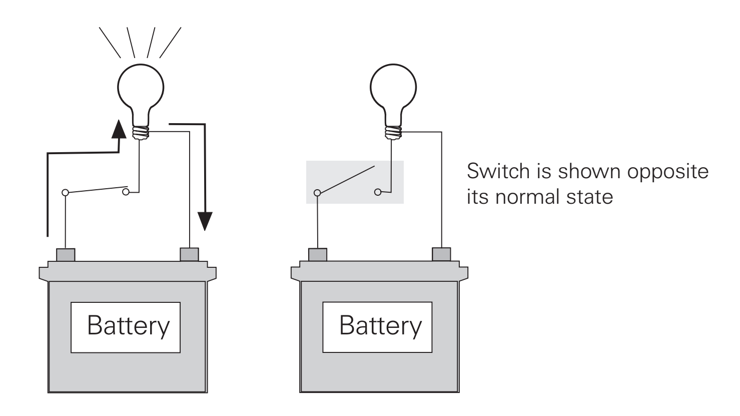
Normally Open Switch Example

In the following illustration, a battery is connected to one side of a normally open switch, and a light is connected to the other side. When the switch is open, current cannot flow through the light. When someone closes the switch, it completes the path for current flow, and the light illuminates.



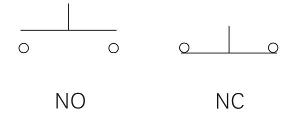
Normally Closed Switch Example

In the following illustration, a battery is connected to one side of a normally closed switch and a light is connected to the other side. When the switch is closed, current flows through the light. When someone opens the switch, current flow is interrupted, and the light turns off.



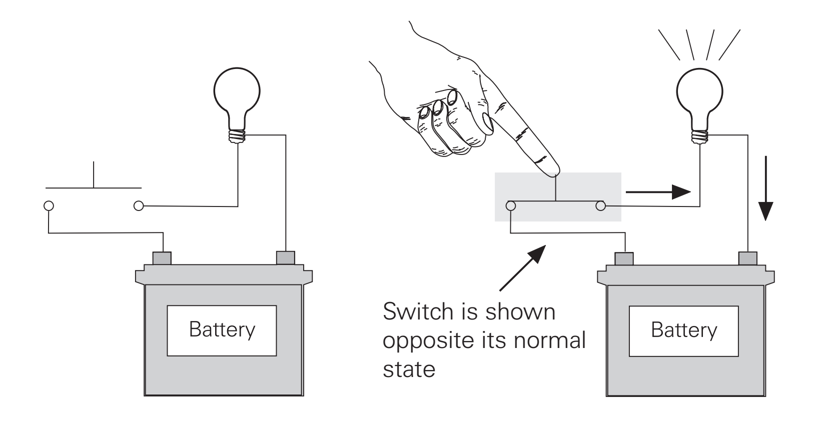
Pushbutton Symbols

There are two general types of **pushbuttons**, **momentary** and **maintained**. The contacts of a momentary pushbutton change state, open to closed or vice versa, when the pushbutton is pressed. They return to their normal state as soon as the button is released. In contrast, a maintained pushbutton latches in place when pressed. It must be unlatched to allow it to return to its normal state.



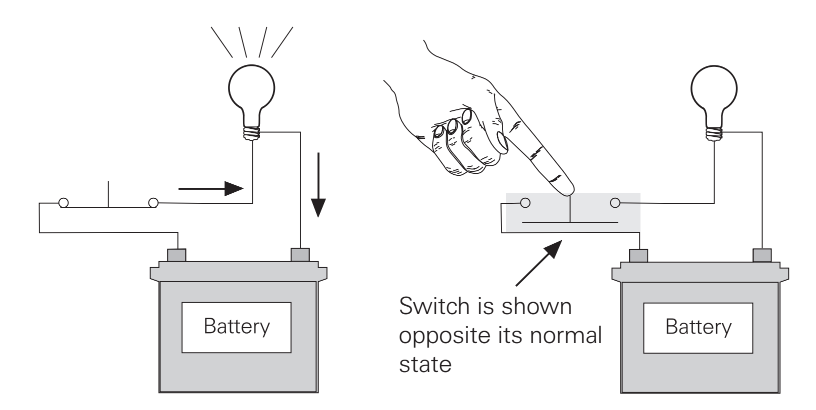
Normally Open Pushbutton Example

In the following illustration, a battery is connected to one side of a normally open pushbutton, and a light is connected to the other side. When the pushbutton is pressed, current flows through the pushbutton, and the light turns on.



Normally Closed Pushbutton Example

In the following example, current flows to the light as long as the pushbutton is not pressed. When the pushbutton is pressed, current flow is interrupted, and the light turns off.



Coil Symbols

Motor starters, contactors, and relays are examples of devices that open and close contacts electromagnetically. The electromagnet in these devices is called a **coil.**

A coil is commonly symbolized as a circle with one or more letters and possibly a number inside. The letters often represent the type of device, such as M for motor starter or CR for control relay. A number is often added to the letter to differentiate one device from another.

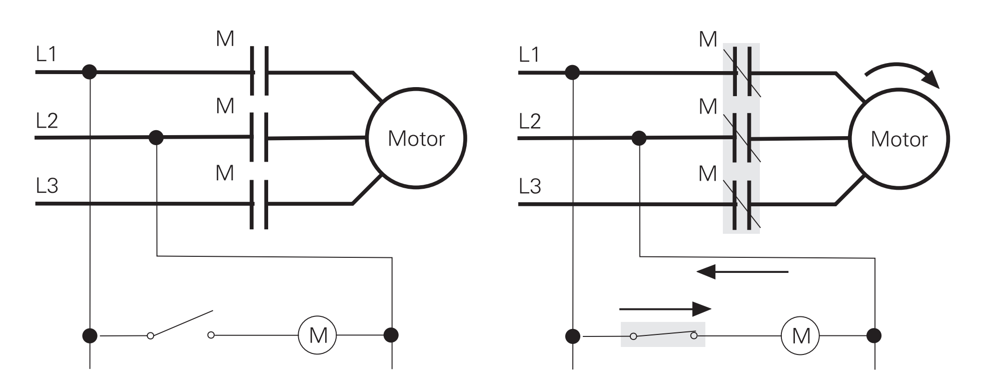
The contacts controlled by a coil are labeled with the same letter (and number) as the coil so that it is easy to tell which contacts are controlled by each coil. A coil often controls multiple contacts and a combination of normally open and normally closed contacts may be used.

M CR

(M) Coil — Associated Contacts; (CR) Coil — Associated Contacts

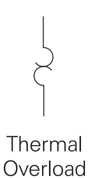
Coil and Contact Example

In the following example, the "M" contacts in series with the motor are controlled by the "M" contactor coil. When someone closes the switch, current flows through the switch and "M" contactor coil. The "M" contactor coil closes the "M" contacts and current flows to the motor.



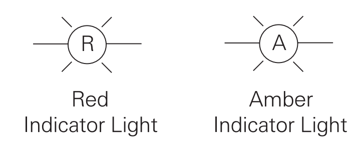
Overload Relay Symbol

Overload relays are used to protect motors from overheating. When excessive current is drawn for a predetermined amount of time, the overload relay's contacts open, removing power from the motor. The following symbol is for contacts associated with a thermal overload relay. An overload relay used with a three-phase motor has three such contacts, one for each phase.



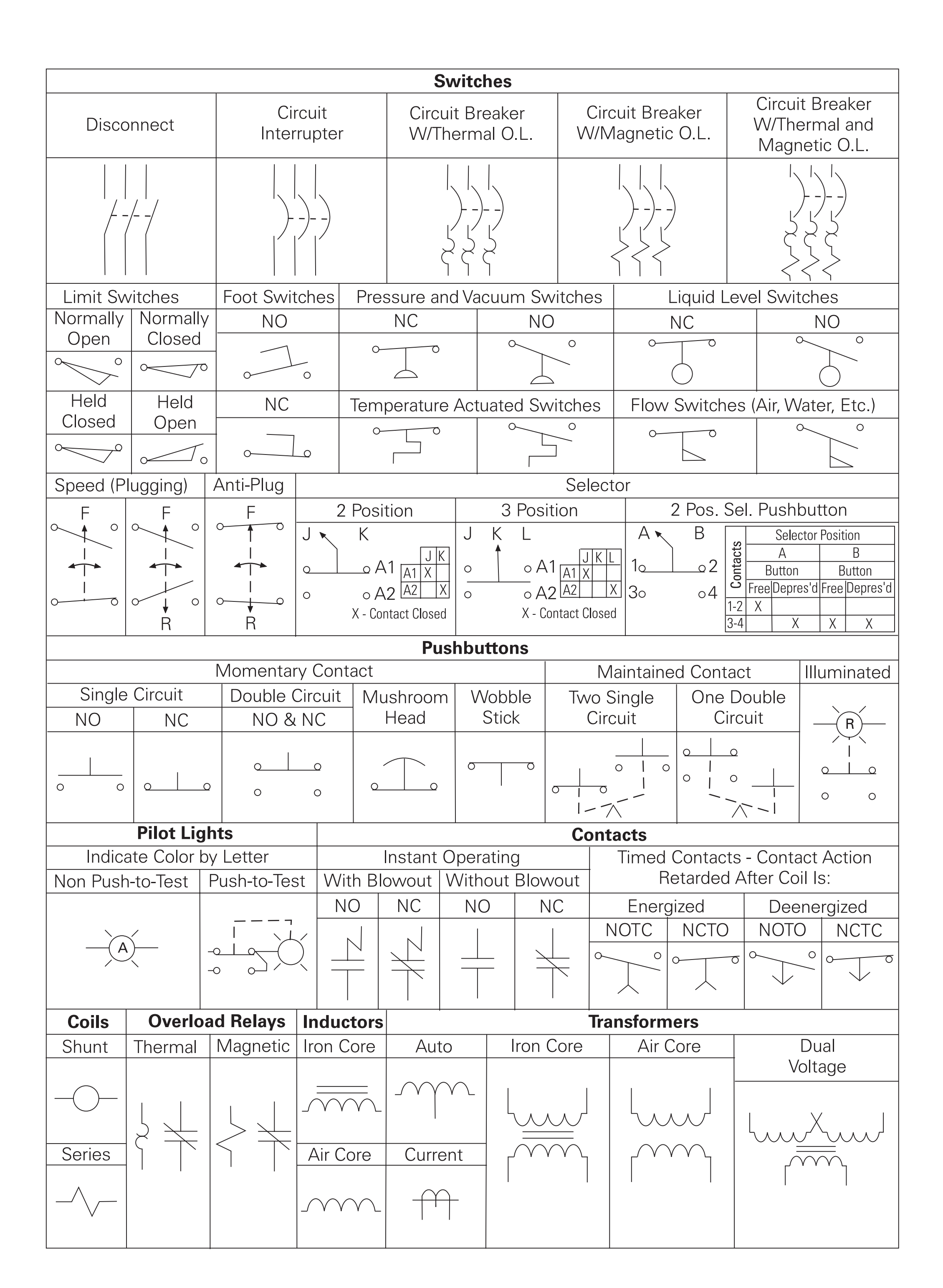
Indicator Light Symbols

An **indicator light**, often referred to as a **pilot light**, is a small electric light used to indicate a specific condition of a circuit. For example, a red light might be used to indicate that a motor is running. A letter in the center of the indicator light symbol is sometimes used to indicate the color of the light.



Other Symbols

In addition to the symbols discussed here, there are many other symbols used in control circuits. The following charts show some of the commonly used symbols.



Switches
Disconnect
Circuit Interrupter
Circuit Breaker W/Thermal O.L.
Circuit Breaker W/Magnetic O.L.
Circuit Breaker W/Thermal and Magnetic O.L.
Limit Switches
Normally Open
Normally Closed
Held Closed
Held Open
Foot Switches
NO
NC
Pressure and Vacuum Switches
NC
NO
Liquid Level Switches
NC
NO
Temperature Actuated Switches
Flow Switches (Air, Water, Etc.)
Speed (Plugging)
Anti-Plug
F
R
Selector
2 Position
3 Position
2 Pos. Sel. Pushbutton
J K
A1
A2
X - Contact Closed
J K L
A B
1 2
3 4
Contacts
Selector Position
A
B
Button
Free
Depres'd
1-2
3-4
Pushbuttons
Momentary Contact
Maintained Contact
Illuminated
Single Circuit
NO
NC
Double Circuit
NO & NC
Mushroom Head
Wobble Stick
Two Single Circuit
One Double Circuit
R
Pilot Lights
Indicate Color by Letter
Non Push-to-Test
Push-to-Test
A
Contacts
Instant Operating
With Blowout
Without Blowout
NO
NC
Timed Contacts - Contact Action Retarded After Coil Is:
Energized
Deenergized
NOTC
NCTO
NOTO
NCTC
Coils
Shunt
Series
Overload Relays
Thermal
Magnetic
Inductors
Iron Core
Air Core
Transformers
Auto
Current
Iron Core
Air Core
Dual Voltage

AC Motors

Single Phase | Three-Phase Squirrel Cage | Wound Rotor

Schematic Wiring

Not Connected | Connected | Power | Control

Battery

+ –

DC Motors

Armature | Shunt Field (Show 4 Loops) | Series Field (Show 3 Loops) | Comm. or Compens. Field (Show 2 Loops)

Meter

Indicate Type by Letter

VM

AM

Meter Shunt | Wiring Terminal | Connections Mechanical

Ground | Mechanical Interlock

Annunciator | Bell | Buzzer | Horn Siren, Etc.

Capacitors

Fixed | Adjustable

Resistors

Fixed (RES) | Heating Element (H) | Adj. By Fixed Taps (RES) | Rheostat Pot Or Adj. Tap (RH)

Half Wave Rectifier

Full Wave Rectifier

AC

+DC –DC

AC

Fuse

Power or Control

Supplementary Contact Symbols

SPST NO		SPST NC		SPDT	
Single Break	Double Break	Single Break	Double Break	Single Break	Double Break

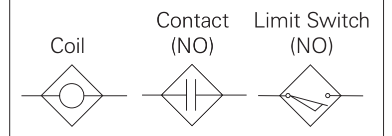
DPST 2 NO		DPST 2 NC		DPDT	
Single Break	Double Break	Single Break	Double Break	Single Break	Double Break

Terms

SPST	Single-Pole Single-Throw
SPDT	Single-Pole Double-Throw
DPST	Double-Pole Single-Throw
DPDT	Double-Pole Double-Throw
NO	Normally Open
NC	Normally Closed

Symbols For Static Switching Control Devices

Static switching control uses solid-state devices instead of electromechanical devices. Many of the symbols used with this type of control are the same as those shown on the previous page, but enclosed in a square as shown in the following examples.



Control and Power Connections - 600 Volts or Less - Across-the-Line Starters (From NEMA Standard ICS 2-321A.60)

		1 Phase	2 Phase 4 Wire	3 Phase
Line Markings		L1,L2	L1,L3-Phase 1 L2,L4-Phase 2	L1,L2,L3
Ground When Used		L1 is always Ungrounded	—	L2
Motor Running Overcurrent Units In	1 Element	L1	—	—
	2 Element	—	L1,L4	—
	3 Element	—	—	L1,L2,L3
Control Circuit Connected To		L1,L2	L1,L3	L1,L2
For Reversing Interchange Lines		—	L1,L3	L1,L3

Abbreviations

Abbreviations are frequently used in control circuits. The following list identifies commonly used abbreviations.

AC	Alternating Current	MTR	Motor
ALM	Alarm	MN	Manual
AM	Ammeter	NEG	Negative
ARM	Armature	NEUT	Neutral
AU	Automatic	NC	Normally Closed
BAT	Battery	NO	Normally Open
BR	Brake Relay	OHM	Ohmmeter
CAP	Capacitor	OL	Overload
CB	Circuit Breaker	PB	Pushbutton
CKT	Circuit	PH	Phase
CONT	Control	POS	Positive
CR	Control Relay	PRI	Primary
CT	Current Transformer	PS	Pressure Switch
D	Down	R	Reverse
DC	Direct Current	REC	Rectifier
DISC	Disconnect Switch	RES	Resistor
DP	Double-Pole	RH	Rheostat
DPDT	Double-Pole, Double-Throw	S	Switch
DPST	Double-Pole, Single-Throw	SEC	Secondary
DT	Double Throw	SOL	Solenoid
F	Forward	SP	Single-Pole
FREQ	Frequency	SPDT	Single-Pole, Double Throw
FTS	Foot Switch	SPST	Single-Pole, Single Throw
FU	Fuse	SS	Selector Switch
GEN	Generator	SSW	Safety Switch
GRD	Ground	T	Transformer
HOA	Hand/Off/Auto Selector Switch	TB	Terminal Board
IC	Integrated Circuit	TD	Time Delay
INTLK	Interlock	THS	Thermostat Switch
IOL	Instanstaneous Overload	TR	Time Delay Relay
JB	Junction Box	U	Up
LS	Limit Switch	UV	Under Voltage
LT	Lamp	VFD	Variable Frequency Drive
M	Motor Starter	XFR	Transformer
MSP	Motor Starter Protector		

Review 1

1. A control is ________ operated when someone must initiate an action for the circuit to operate.

2. Identify each of the following symbols.

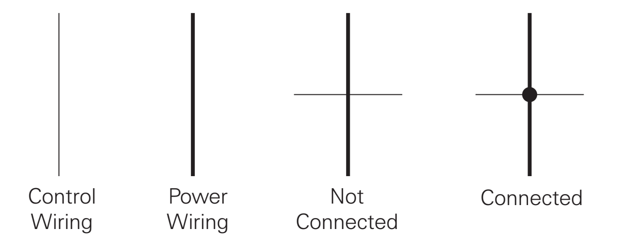
   a. b. c.

3. Which of the following symbols represents a normally open pushbutton?

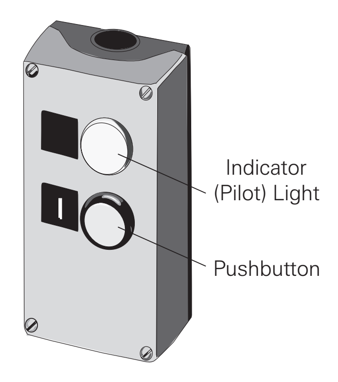
   a. b. c.

Line Diagrams

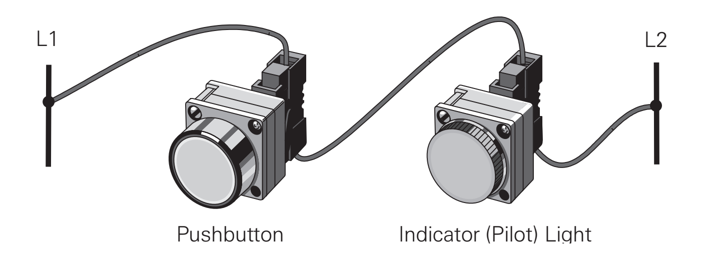
Control symbols are used in **line diagrams**, also referred to as **ladder diagrams**. Line diagrams are made up of two types of circuits, control circuits and power circuits. Within a line diagram, control circuit wiring is represented by a light line, and power circuit wiring is represented by a heavy line. A small dot or node at the intersection of two or more wires indicates an electrical connection.



Line diagrams show the functional relationship of components in an electrical circuit, not the physical relationship. For example, the following illustration shows the physical relationship of an indicator light and a pushbutton.

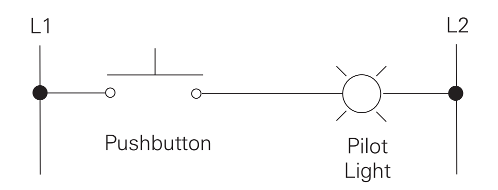


The functional relationship can be shown pictorially with the following illustration.



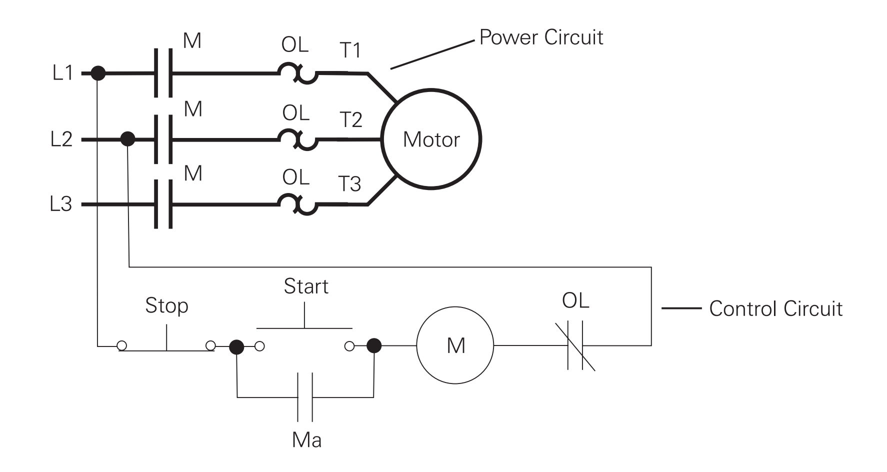
Reading a Line Diagram

The following line diagram symbolically displays the functional relationship of these same components. In order to properly interpret this diagram, you must read it starting at L1 from left to right to L2. With that in mind, note that pressing the pushbutton allows current to flow from L1 to L2 through the pushbutton and the pilot light. Releasing the pushbutton stops current flow, turning the indicator light off.

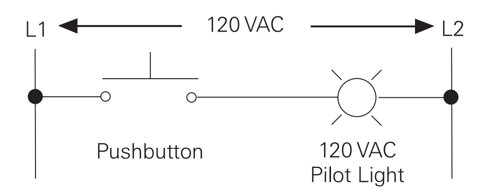


Power and Control Circuits

The following line diagram includes both power and control circuits. The **power circuit**, drawn with a heavy line, is the circuit that supplies power to the motor. The **control circuit,** drawn with a light line, controls the distribution of power.



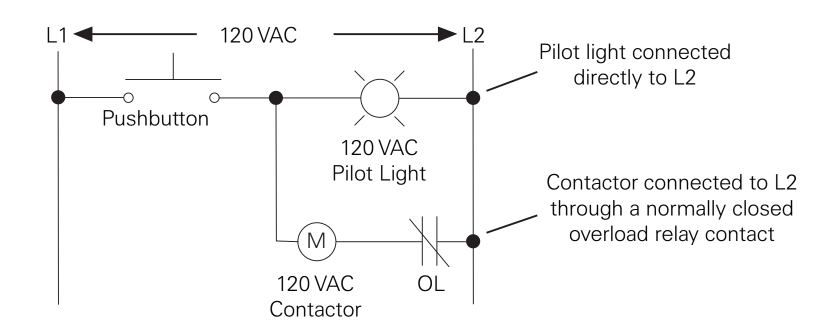
A typical control circuit includes a control load and one or more components that determine when the control load will be energized. Some control loads, such as relays and contactors, activate other devices, but other control loads, such as indicator lights, do not. For example, the following illustration shows the connection of an indicator light and a pushbutton. The power lines are drawn vertically and marked L1 and L2. In this example, the voltage between L1 and L2 is 120 VAC. This means that the indicator light must be rated for 120 VAC, because, when the pushbutton is pressed, 120 VAC is applied to the indicator light.



Connecting the Load to L2

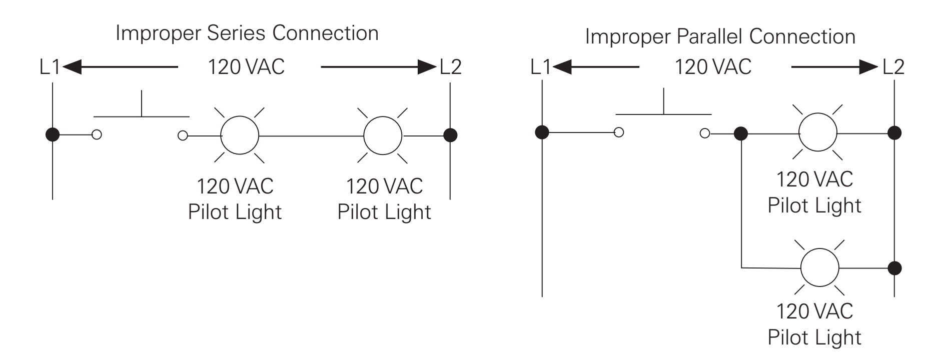
Only one control load can be placed in any one circuit line between L1 and L2. One side of the control load is either directly or indirectly connected to L2.

In the following example, an indicator light is directly connected to L2 on one circuit line. A contactor coil is indirectly connected through a set of overload contacts (OL) to L2 on a second, parallel circuit line. Pressing the pushbutton applies 120 VAC to the indicator light and to the "M" contactor.



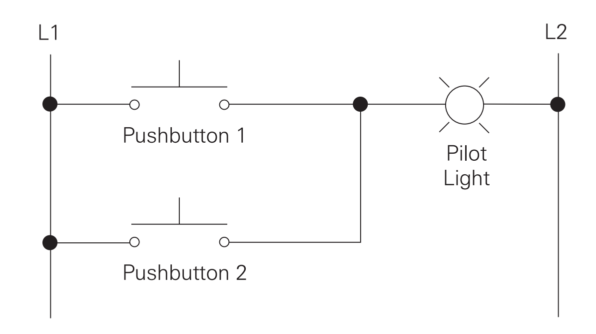
Control loads are generally not connected in series. The following illustration shows why. In the circuit on the left, the control loads are improperly connected in series. When the pushbutton is pressed, the voltage across L1 and L2 is divided across both loads with neither load receiving the full 120 VAC necessary for proper operation.

In the circuit on the right, the loads are properly connected in parallel, and, when the pushbutton is pressed, the full 120 VAC is applied to both loads. In addition, if one load fails in this configuration, the other load will continue to operate normally.

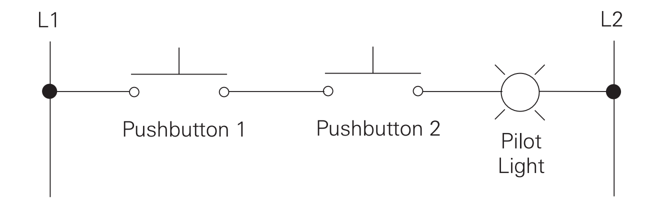


Connecting Control Devices

In the previous example, only one control device is used to control the load. Usually more than one control device is needed. These control devices may be connected in series, parallel, or in a combination series-parallel circuit, depending on the logic required to control the load. For example, in the following illustration, the pushbuttons are connected in parallel. Pressing either pushbutton, or both pushbuttons, allows current to flow from L1, through the indicator light, to L2.

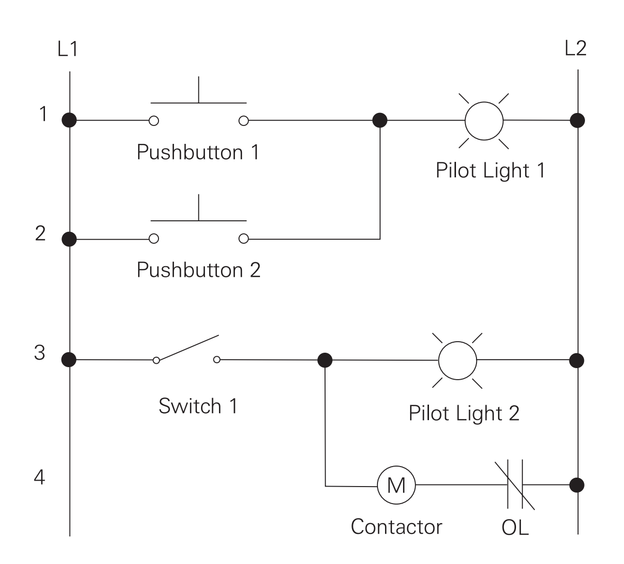


The next illustration shows two pushbuttons connected in series. Both pushbuttons must be pressed at the same time to allow current to flow from L1 through the load to L2.



Line Numbering

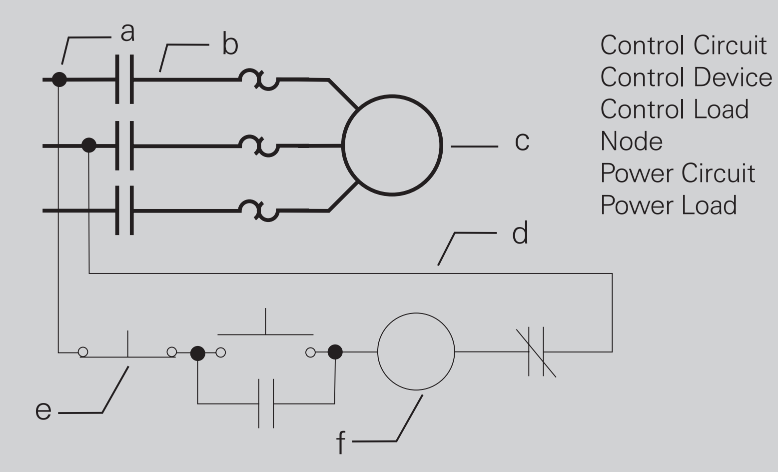
Because line diagrams often have multiple lines, the lines are often numbered to simplify describing the logic. For example, in the following illustration, line 1 connects pushbutton 1 to pilot light 1, line 2 connects pushbutton 2 to pilot light 1, and line 3 connects switch 1 to pilot light 2 and to the “M” contactor on line 4.



Review 2

1. Line diagrams are read starting at L1 from ________ to ________ to L2.

2. Match the items on the line diagram with the associated list.



a. ________ b. ________ c. ________

d. ________ e. ________ f. ________

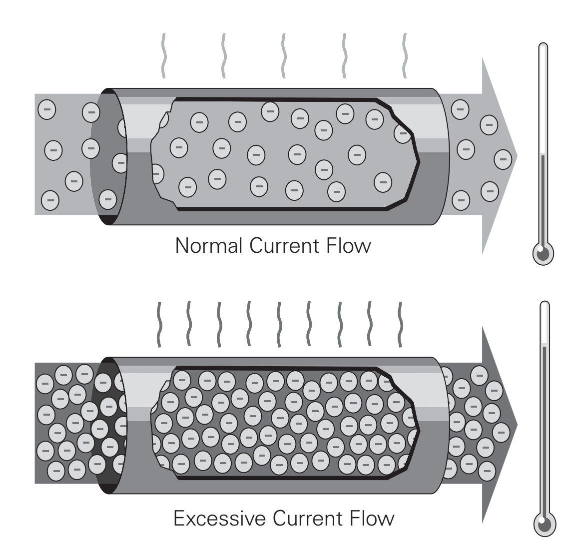
Overload Protection

Some of the control components covered in this course are designed to protect motors from overloads. In order to understand these control components, you must have a clear understanding of what an overload is and how it differs from a short circuit, another type of overcurrent condition.

Current and Temperature

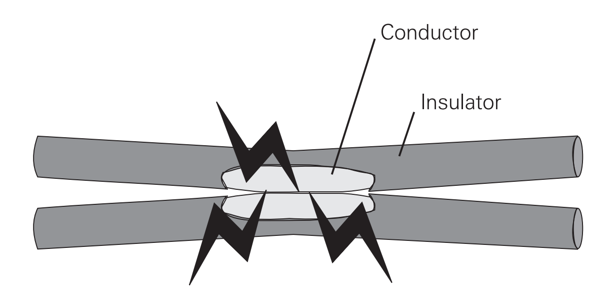
To begin with, current flow always generates heat. The amount of heat generated is proportional to both the amount of current flow and the resistance of conductive path. Keep in mind that conductors can be damaged by excess heat. For that reason, each conductor has a continuous current rating, also called its **ampacity**.

Excessive current is referred to as **overcurrent**. An overcurrent may result from a short circuit, overload, or ground fault. The first two types of overcurrent conditions are pertinent to this discussion.



Short Circuits

Normally, the insulation used to separate conductors prevents current from flowing between the conductors. When the insulation is damaged; however, a short circuit can result. A **short circuit** occurs when bare conductors touch and the resistance between the conductors drops to almost zero. This reduction in resistance causes current to rise rapidly, usually to many times the normal circuit current.



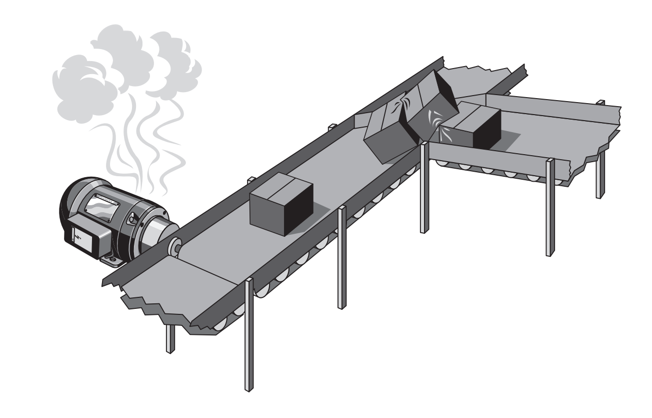
To understand this better, consider the relationship between current and resistance described by **Ohm's Law**. For example, if the voltage in a circuit is 240 volts and the resistance is 24 ohms, the current is 10 amps. When a short circuit occurs, the resistance between conductors drops to a very low value, 0.024 ohms in this example. Note that this causes the current to rise proportionally.

	Before Short Circuit	After Short Circuit
Ohm's Law $I = \frac{E}{R}$	$I = \frac{240\ V}{24\ \Omega} = 10\ A$	$I = \frac{240\ V}{0.024\ \Omega} = 10{,}000\ A$

The heat generated by this current will cause extensive damage to connected equipment and conductors if not interrupted immediately by a circuit breaker or fuse.

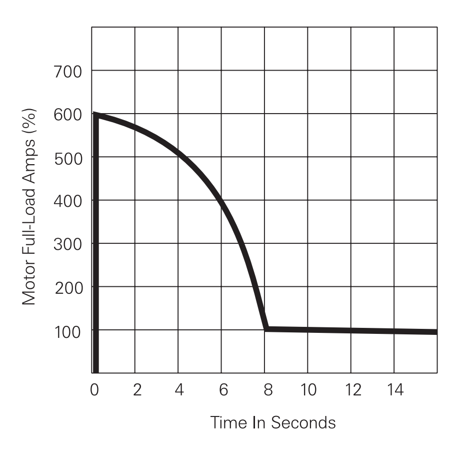
Overloads

In contrast, an **overload** is a much lower current than a short circuit. An overload occurs when too many devices are connected to a circuit or when electrical equipment is made to work beyond its rated capabilities. For example, if a conveyor jams, its motor may draw two or more times its rated current.



In the previous example, the overload resulted when a circuit exceeded its rated capacity for an extended time. In such a situation, an overcurrent protection device should shut down the circuit.

A different response is required for a short-duration overload. In such a situation, it may be undesirable to disable the circuit. To understand this better, consider what happens when an electric motor is started. When most motors start, they draw current in excess of their full-load current rating. For example, a NEMA design B motor typically has a **starting current** that is about six times its **full-load current**. For some high-efficiency motors, the starting current is even higher. Motors are designed to tolerate a high starting current for a short time. As a motor accelerates to operating speed, its current drops off quickly. In the following example, the motor's starting current is 600% of full load current, but after eight seconds, current has dropped to the rated value.

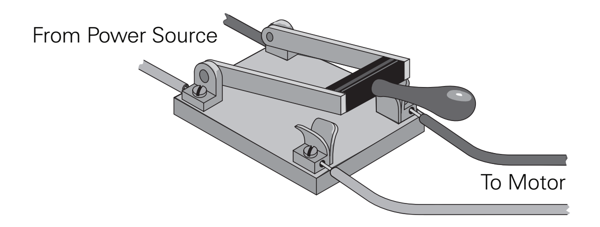


Overload Protection

Fuses and circuit breakers are designed to protect circuit conductors in the event of a short circuit or overload. Under such conditions, these devices open the path for current flow before damage to conductors occurs. In a motor circuit, circuit conductors and the fuse or circuit breaker designed to protect them must be sized to allow for the high starting current of the motor. Because of this, overload protection for the motor must be provided by a separate device known as an **overload relay**.

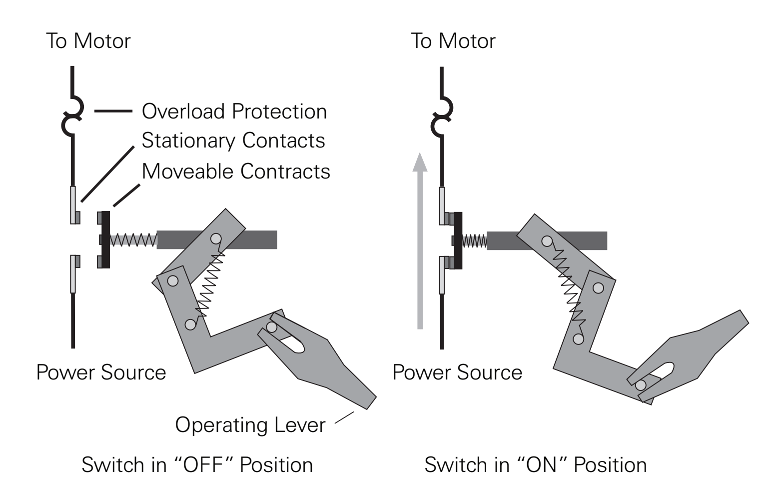
Manual Control

As the name implies, manual controls are devices operated by hand. A simple knife switch, like the one shown in the following illustration, was the first manual-control device used to start and stop motors. The knife switch was eventually replaced with improved control designs such as manual and magnetic starters.

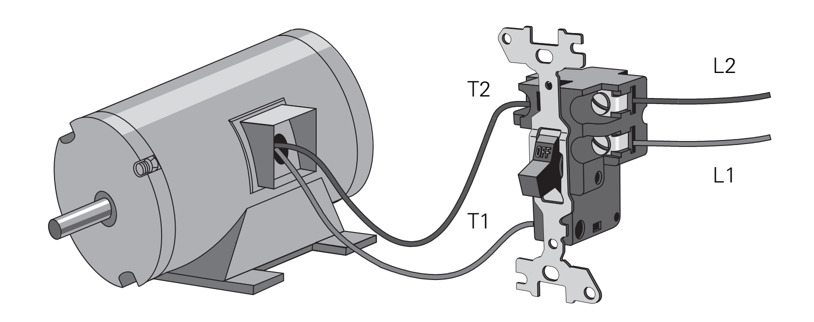


In addition to turning a motor on and off, a motor control device may also provide overload protection for the motor. To accomplish these tasks, manual starters combine a manual contactor or switch mechanism and an overload protection device.

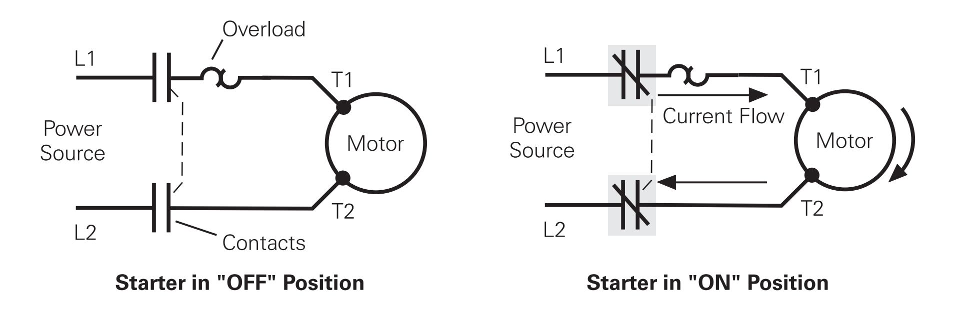
The following diagram illustrates a single-pole manual motor starter. Each set of contacts is called a **pole**. A starter with two sets of contacts would be called a two-pole starter.



Starters are connected between the power source and the load. In the following example, a two-pole or single-phase motor starter is connected to a motor. When the switch is in the "OFF" position, the contacts are open, preventing current flow to the motor from the power source. When the switch is in the "ON" position, the contacts are closed, and current flows from the power source (L1), through the motor, then returning to the power source (L2).



This is represented with a line drawing like the one shown in the following illustration.

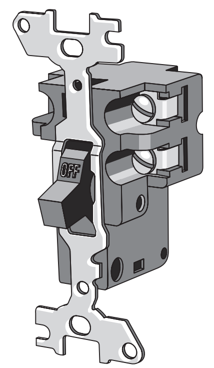


Some manual motor starters offer **low-voltage protection (LVP)** as an option. LVP automatically removes power from the motor when incoming power drops or is interrupted.

An LVP starter must be manually reset when power is restored. This protects personnel from potential injury caused by machinery that would otherwise automatically restart when power is restored.

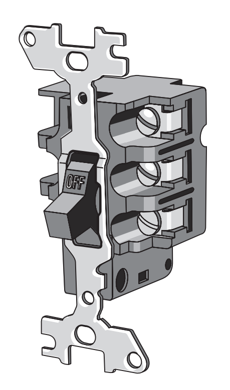
Siemens Manual Starters and Switches

Siemens **SMF fractional-horsepower starters** provide overload protection and manual “ON/OFF” control for small motors. SMF starters are available in one-pole or two-pole versions suitable for AC motors up to 1 HP and 277 VAC. The two-pole version is suitable for DC motors up to 3/4 HP and 230 VDC. A melting-alloy type overload relay is used for overload protection. SMF manual starters are available in a variety of enclosures. A two-speed version is also available.



Two-Pole Manual Starter

Siemens **MMS and MRS switches** are similar to SMF starters but do not provide overload protection. MMS and MRS switches only provide manual “ON/OFF” control of DC and single-phase or three-phase AC motors where overload protection is provided separately. These devices are suitable for use with three-phase AC motors up to 10 HP and 600 VAC and up to 1-1/2 HP and 230 VDC. The MMS and MRS manual switches are available in various enclosures. Two-speed and reversing versions are also available.



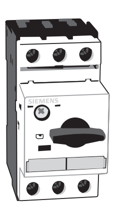
Three-Pole Manual Switch

Siemens Class 11 across-the-line manual starters and switches provide control for machinery where remote start and stop control is not required.

Class 11 - 3RV manual starters are used for single-phase and three-phase motors up to 15 HP at 460 VAC and have bimetallic heater elements that provide class 10 overload protection. These starters have ambient temperature compensation. A built-in differential trip bar reduces tripping time in the event of a phase loss condition.

Class 11 - 3RV switches provide control where overload protection is not required or is provided separately.

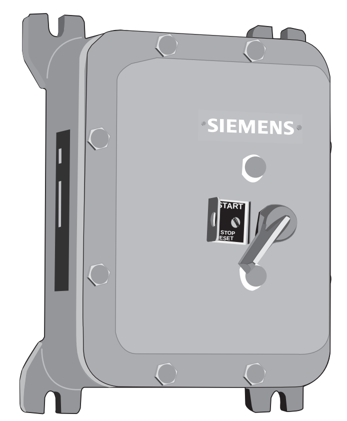
Class 11 - 3RV controllers are available with low voltage protection which automatically opens the power poles when the voltage drops or power is interrupted. They are available in an open style (without enclosure), in NEMA 1 general purpose enclosures, and in NEMA 7 & 9 or NEMA 3 & 4/NEMA 7 & 9 enclosures (for hazardous locations).



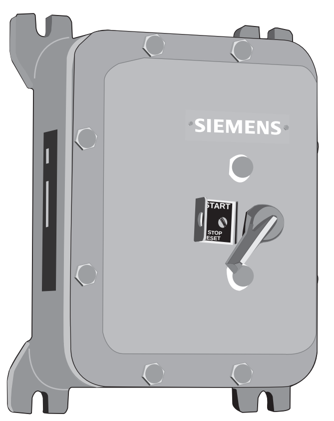
Open Type
Starter



NEMA 1 Enclosure



NEMA 7 & 9
Class I Group C &D
Class II Group E, F & G



NEMA 3 & 4, NEMA 7 & 9
Class I Group C &D
Class II Group E, F & G

Motor Starter Protectors

Motor starter protector (MSP) is a name used in the U.S. and some other countries to identify a type of component that is referred to in International Electrotechnical Commission (IEC) standards as a circuit breaker. Siemens 3RV MSPs are part of the SIRIUS modular system of control products described throughout this course.

3RV1 Motor Starter Protectors feature a manual on/off switch, a Class 10 adjustable thermal overload relay (Class 20 available in the two largest frame sizes), and magnetic trip elements for short circuit protection.

3RV1 MSPs are UL listed as manual motor controllers per UL 508, making them appropriate for manual starting and stopping applications where upstream short-circuit protection is provided. 3RV102, 3RV103, and 3RV104 MSP's can be used as Type E self-protected manual combination starters per UL 508 (3RV102 and 3RV104 require additional terminal adapters) or as components in group installation per NEC 430-53(C) to turn motors on and off.

3RV2 MSPs are available in sizes S00 and S0 up to 40 A with screw-type, spring-loaded, or ring cable lug connections. 3RV2 MSPs are part of the SIRIUS Innovations addition to the SIRIUS modular system as discussed later in this course. Among other advantages, 3RV2 motor starter protectors have 5 to 10 percent lower power losses than previous models thanks to new bimetal technology. This plays an important role in reducing the temperature within the control cabinet.

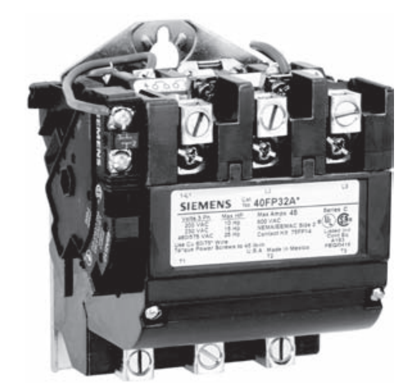


Spring-loaded Terminals Screw-type Terminals
3RV2 Motor Starter Protectors

Magnetic Contactors

NEMA and IEC Contactors

Most motor applications require the use of remote control devices to start and stop the motor. **Magnetic contactors**, similar to the ones shown below, are commonly used to provide this function. As discussed later in this course, some magnetic contactors are used to control the distribution of power in lighting and heating circuits.



NEMA Contactor

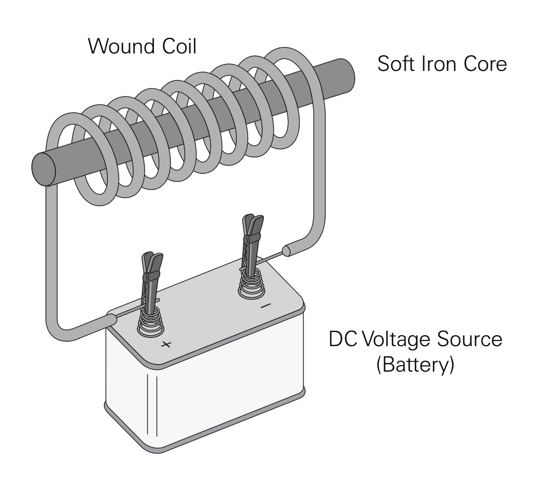


IEC Contactor

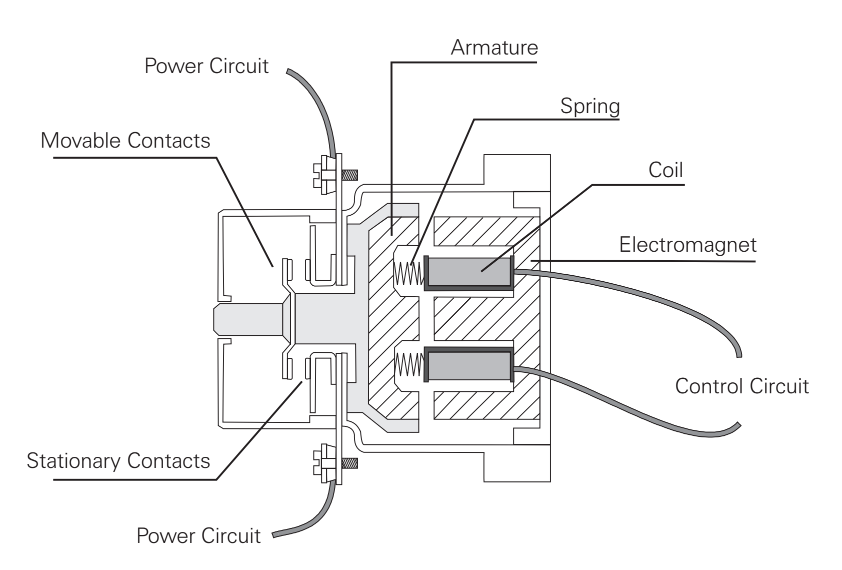
Like many other control components, contactors are most often manufactured to specifications provided either by the **National Electrical Manufacturer's Association (NEMA)** or the **International Electrotechnical Commission (IEC)**.

Basic Contactor Operation

Magnetic contactors utilize basic electromagnetic principles. To understand these principles, consider a simple **electromagnet** fashioned by winding a wire around a soft iron core and connecting the coil to a DC voltage source. Current flowing through the wire temporarily magnetizes the iron core coil. When the coil is disconnected from the DC voltage, the current stops and the iron core coil returns to its nonmagnetic state.

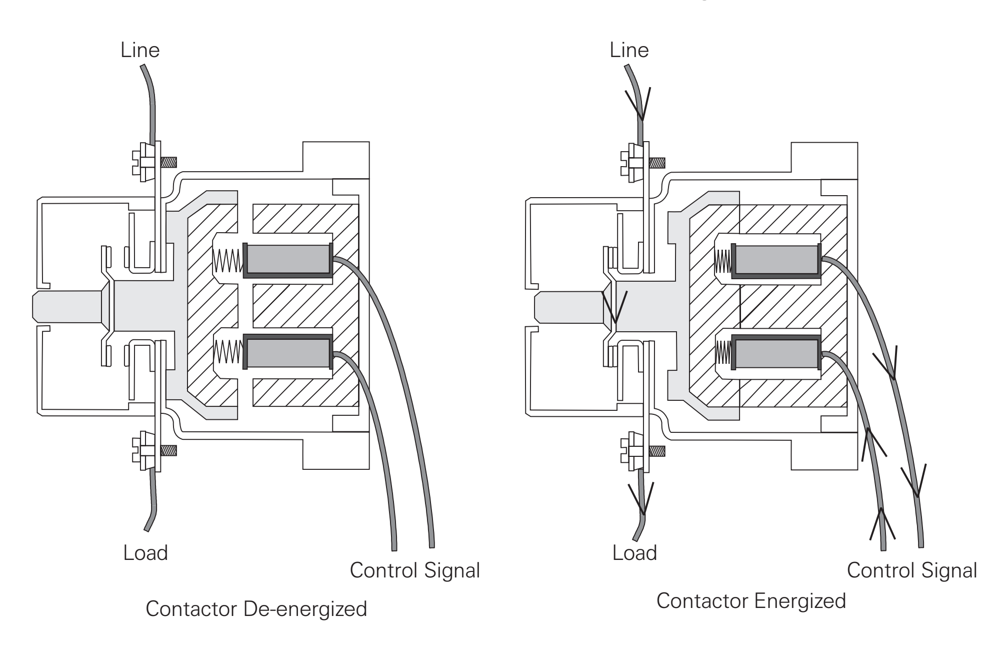


The following illustration shows the interior of a basic contactor. There are two circuits involved in the operation of a contactor, the control circuit and the power circuit. The control circuit is connected to the coil of an electromagnet, and the power circuit is connected to the stationary contacts.



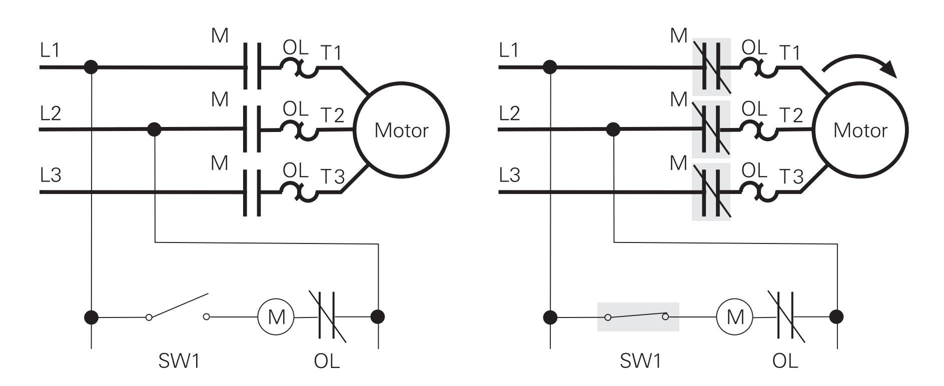
The operation of this electromagnet is similar to the operation of the electromagnet made by wrapping wire around a soft iron core. When power is supplied to the coil from the control circuit, a magnetic field is produced, magnetizing the electromagnet. The magnetic field attracts the armature to the magnet, which in turn closes the contacts. With the contacts closed, current flows through the power circuit from the line to the load.

When current no longer flows through the control circuit, the electromagnet's coil de-energizes, the magnetic field collapses, and the movable contacts open under spring pressure.



The following line diagram shows a contactor that provides on-off control for a three-phase motor. Note that the power to the electromagnetic coil of this contactor is controlled by SW1.

When SW1 closes, the electromagnetic coil energizes, closing the "M" contacts and applying power to the motor. When SW1 opens, the coil de-energizes, opening the "M" contacts and removing power from the motor.



Review 3

1. With an increase in current, heat ________.

2. Excessive current is referred to as ________.

3. An ________ occurs when too many devices are connected to a circuit or when electrical equipment is made to work beyond its rated capabilities.

4. Some manual motor starters offer ________ protection which automatically removes power from the motor when incoming power drops or is interrupted.

5. Siemens ________ fractional horsepower starters provide overload protection and manual on/off control for small motors.

6. Siemens ________ and ________ switehes provide manual on/off control of DC and single-phase or three-phase AC motors where overload protection is provided separately.

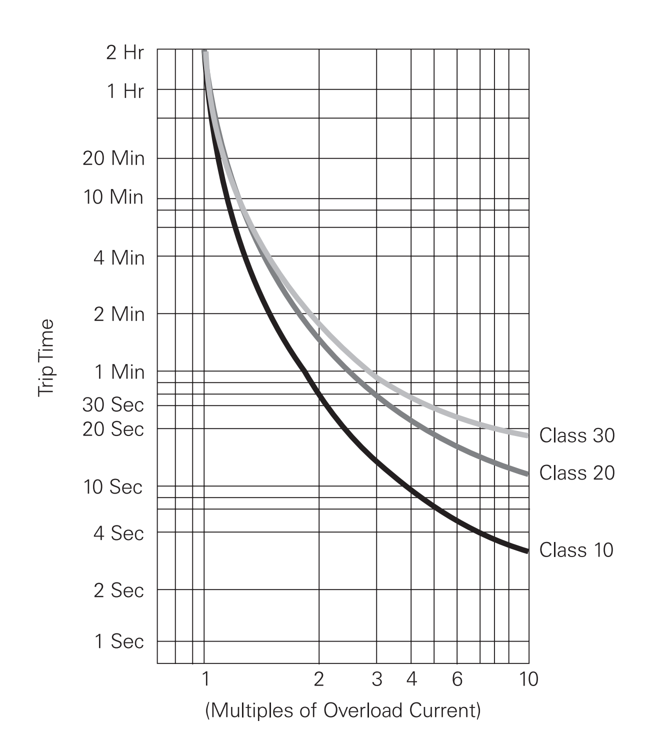
7. _________ is a name given in the U.S. and some other countries to a type of IEC circuit breaker that is used for manual motor control.

8. ________ are used to remotely start and stop motors or control the distribution of power in lighting and heating applications.

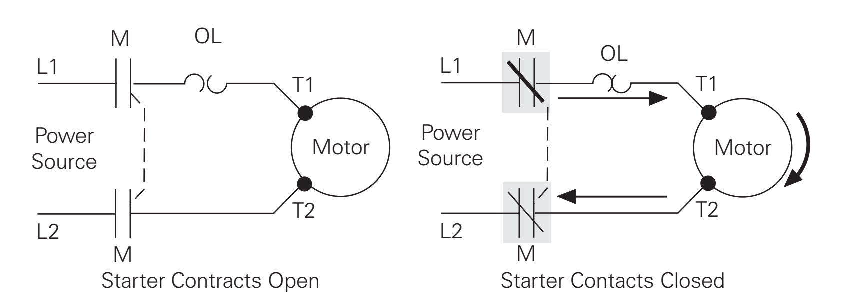
Overload Relays

Overload relays are designed to meet the special protective needs of motors. Overload relays do not disable the circuit during a short-duration overload, but will trip and open a circuit to protect a motor if current remains above the rated value long enough. After an overload relay has tripped and the cause of the overload has been cleared, the overload relay can be reset to allow the motor to be restarted.

An overload relay has a **trip class** rating which identifies the maximum time (in seconds) it takes for the overload relay to trip at a specific current, typically six times its continuous current rating. The most common trip classes are 5, 10, 20, and 30.



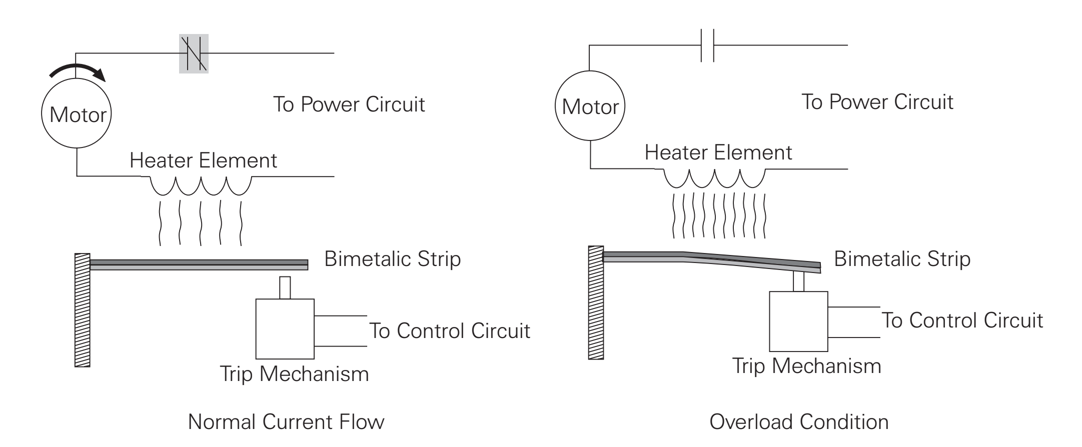
The following illustration shows a circuit with a manual motor starter (M) and an overload relay (OL). When the starter contacts close, current flows through the overload relay and motor. If the motor is overloaded, excess current will cause the overload relay to trip, opening the circuit between the power source and the motor. After the overload relay cools, it can be reset. This allows the motor to be restarted, preferably after the cause of the overload has been corrected.



Thermal Overload Relays

Thermal overload relays, also called **bimetal overload relays,** use a **bimetallic strip** to sense an overload condition. A thermal overload relay incorporates a small **heater element** wired in series with the motor and a bimetallic strip that functions as a trip lever. The bimetallic strip is made of two dissimilar metals bonded together. These metals have different thermal expansion characteristics, causing the bimetallic strip to bend when heated.

Under normal operating conditions, the heat generated by the heater element causes the bimetallic strip to bend only slightly, not enough to trip the overload relay. If an overload condition occurs and persists long enough, the bimetallic strip bends until the overload relay's trip mechanism is tripped. This causes the overload relay's contacts to open, removing power from the motor.

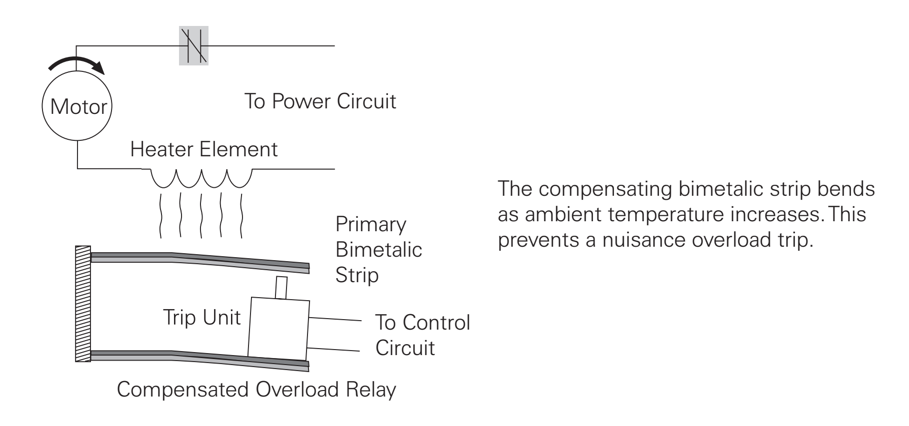


Some thermal overload relays are designed to reset automatically after the bimetallic strip has cooled. Depending on the circuit, the motor may then restart automatically. In some applications, this is desirable. However, if the cause of the overload still exists, the overload relay will trip and reset repeatedly. Proper circuit design can prevent this condition, which can damage the motor.

Ambient Temperature Compensation

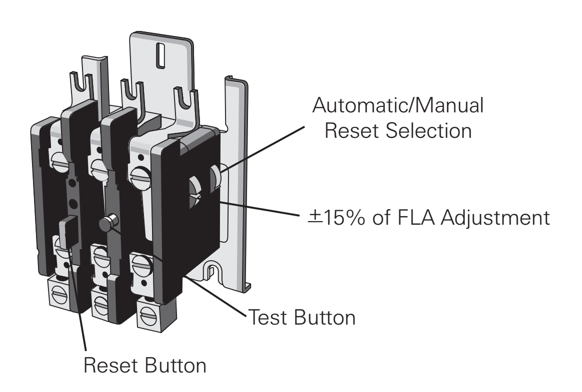
In some applications, a motor is installed in a location with a relatively constant ambient temperature, and the motor control components are installed in a location with a varying ambient temperature. In such cases, a typical thermal overload relay may trip too soon or too late because its bimetallic strip is bent both by heat from motor current and the surrounding air.

Ambient compensated thermal overload relays are designed to overcome this problem. These overload relays use a compensated bimetallic strip along with a primary bimetallic strip. As the ambient temperature changes, both bimetallic strips bend equally and the overload relay does not trip. However, because current flow through the motor and the heater element affects only the primary bimetallic strip, the primary bimetallic strip will bend sufficiently to trip the overload relay if an overload occurs.



Siemens **Class 48 ambient compensated thermal overload relays** are available in single-pole or three-pole designs and can be set for manual or self-resetting operation. An adjustment dial allows the full load ampere (FLA) trip setting to be adjusted by ±15%. A manual test button is provided to test the operation of the overload relay control contacts.

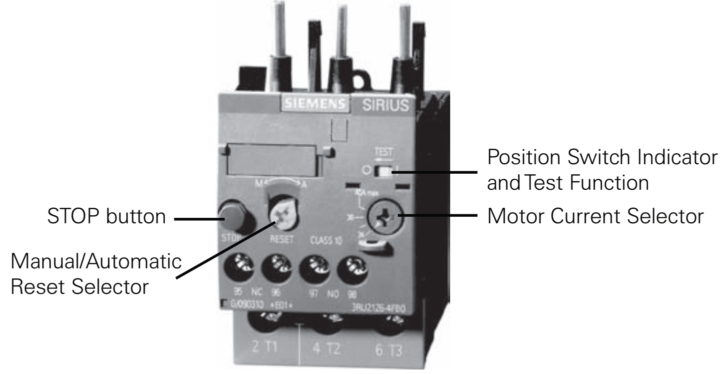
The ambient compensated thermal overload relay heater elements are available with either class 10 or 20 ratings. A normally open or normally closed auxiliary contact is available as an option.



Siemens **SIRIUS 3RU thermal overload relays** are available in single-phase and three-phase designs. They feature a Class 10 trip, manual or automatic reset selection, adjustable current settings, ambient temperature compensation, and a differential trip bar that causes the unit to trip faster in the event of a phase loss.

SIRIUS 3RU overload relays include a normally closed auxiliary contact for de-energizing the contactor and a normally open auxiliary contact for signaling an overload trip. Pressing the STOP button momentarily opens the normally closed contact without affecting the normally open contact. The switch-position indicator incorporates a Test function which, when activated, simulates a tripped overload relay by activating both auxiliary contacts and displaying the switch position.

SIRIUS 3RU1 thermal overload relays are available with current ratings up to 100 A. SIRIUS 3RU2 thermal overload relays are part of the SIRIUS Innovations addition to the SIRIUS modular system as discussed later in this course and are available with current ratings up to 40 A.



SIRIUS 3RU2 Thermal Overload Relay

Electronic Overload Relays

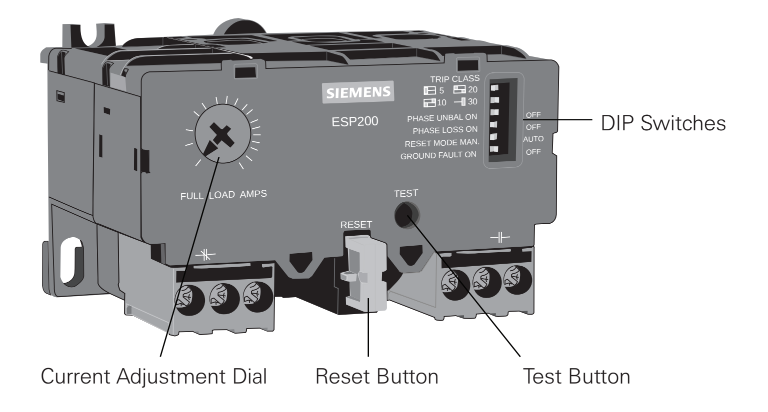
Electronic overload relays are another option for motor protection. The features of electronic overload relays vary, but there are a few common advantages. One advantage of electronic overload relays is that they do not require heaters. This eliminates the need to stock multiple heaters to match motor ratings. This heaterless design also allows electronic relays to be insensitive to the ambient temperature, minimizing nuisance tripping.

In addition, unlike some thermal overload relays, most electronic overload relays can detect a power phase loss and disconnect the motor from the power source. This is an important advantage because, without phase lose protection, loss of a power phase can quickly result in damaged motor windings.

Like other electronic overload relays, **ESP200 electronic overload relays** eliminate the need for heaters. Instead of installing a heater, a dial on the overload relay is set to the motor's full-load ampere (FLA) rating.

Class 48 ESP200 electronic overload relays, like the one shown below, have two dual in-line package (DIP) switches accessible from the front that simplify the trip class selection of any of four trip classes (5, 10, 20, and 30).

Additional DIP switches provide on or off settings for phase unbalance, phase loss, or ground fault detection as well as selection of manual or automatic reset. Also accessible from the front are the RESET button, for use when manual reset is selected, and the TEST button, that triggers a complete electronic functions test. One normally open auxiliary contact and one normally closed auxiliary contact are standard.



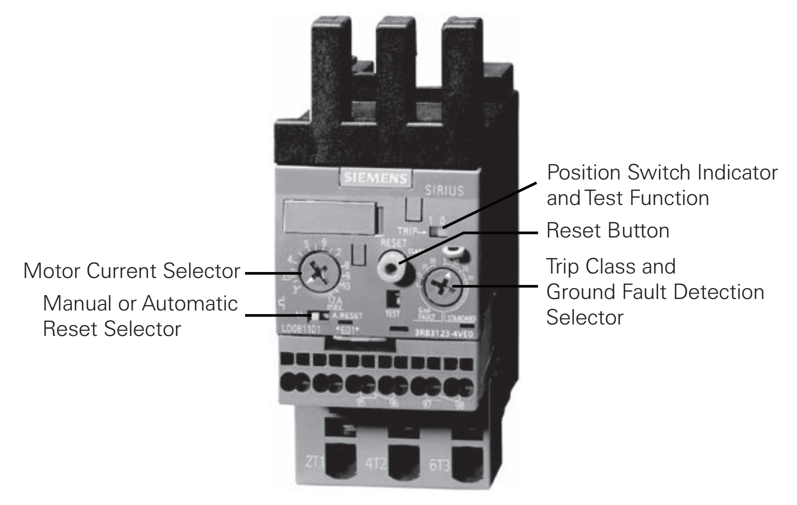
In addition to Class 48 ESP200, two other types of ESP200 electronic overload relays are available. **958 ESP200 electronic overload relays** are specifically designed for sealed compressors and artificially-cooled motors. **958L electronic overload relays** are specifically designed for the oil market and pumping applications with a precise trip curve.

SIRIUS is Siemens modular system of control components designed to IEC specification. **SIRIUS 3RB20/21 electronic overload relays** are available with current ratings up to 630 A. **SIRUIS 3RB30/31 electronic overload relays** are part of the SIRIUS Innovations addition to the SIRIUS modular system and are available with current ratings up to 40 A.

SIRIUS 3RB20 and 3RB30 electronic overload relays come with a class 10 or 20 trip and feature manual or automatic reset, adjustable current settings, and ambient temperature compensation. A normally closed auxiliary contact for de-energizing the contactor and a normally open auxiliary contact for signaling an overload trip are included.

Pressing the STOP button momentarily, opens the normally closed contact without affecting the normally open contact. The switch-position indicator incorporates a TEST function which, when activated, simulates a tripped overload relay by actuating both auxiliary contacts and displaying the switch position.

SIRIUS 3RB21 and 3RB31 electronic overload relays have similar features to SIRIUS 3RB20 and 3RB30 overload relays, but allow the trip class to be set from 5 to 30 and have a ground fault detection function that can be enabled.



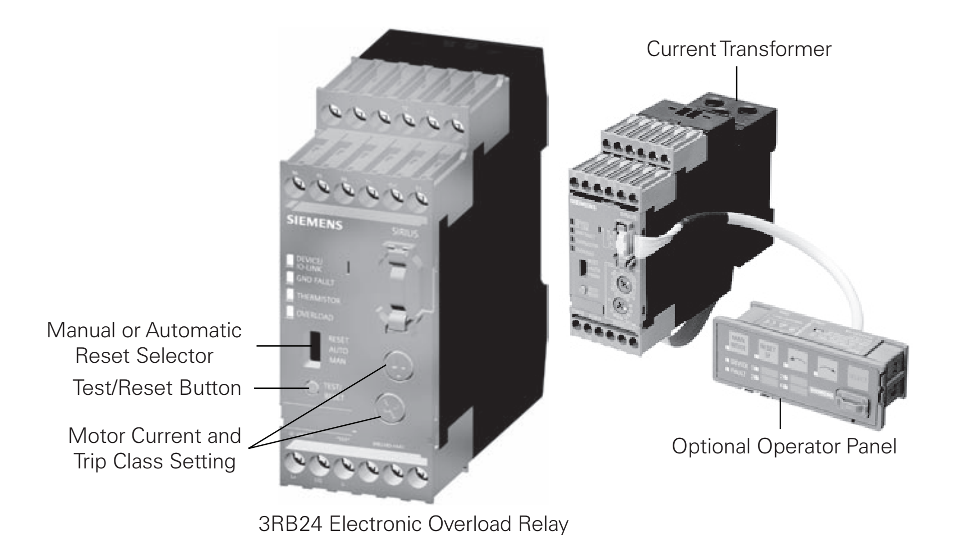
3RB31 Electronic Overload Relay

SIRIUS 3RB22/23 electronic overload relays are available with current ratings up to 630 A (up 820 A with an optional module). These overload relays provide trip class adjustments from class 5 to 30 and ground fault, phase imbalance, and phase loss protection. Motor current is continuously monitored in each phase.

Two auxiliary contacts, one normally open and one normally closed, are switched in the event of an overload, phase imbalance, or phase loss. One additional set of auxiliary contacts, one normally open and one normally closed, are switched without time delay in the event of a ground fault.

In addition to sensing current, SIRIUS 3RB22/23 overload relays directly sense motor winding temperature via a thermistor sensor. With an additional AS-Interface analog module, 3RB22/23 overload relays can communicate via the **AS-Interface** bus, described later in this course, to share operational data, diagnostics, and parameter settings with a PLC or other control system.

SIRIUS 3RB24 electronic overload relay has similar features to SIRIUS 3RB22/23 electronic overload relays, but has **IO-Link** communication capability (described later in this course), which is ideal for use in a limited area, such as a control cabinet.



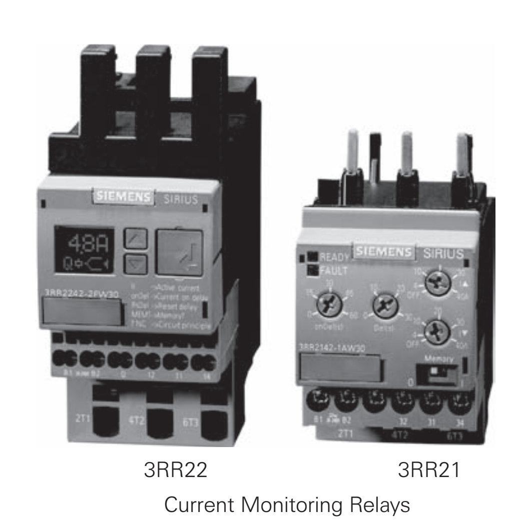
3RB24 Electronic Overload Relay

Current Monitoring Relays

SIRIUS 3RR2 current monitoring relays are part of the SIRIUS Innovations addition to the SIRIUS modular system and are available with current ratings up to 40 A.

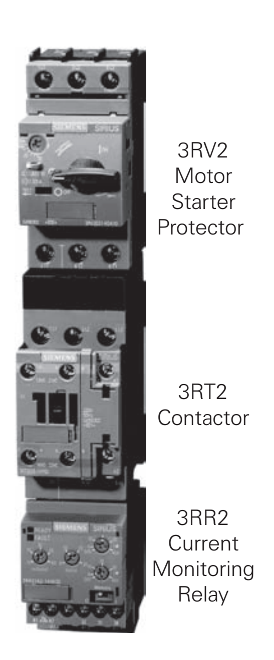
Although a SIRIUS 3RR2 current monitoring relay monitors motor current and can be directly mounted to a SIRIUS 3RT2 contactor in place of an overload relay, it provides more than motor protection. Because variations in motor current can indicate a variety of machine or process problems, SIRIUS 3RR2 current monitoring relays provide a means for direct monitoring and protection of the application and can be very helpful in reducing system downtime and maintenance expense.

SIRIUS 3RR2 current monitoring relays are available in two versions. 3RR21 is a two-phase basic version with potentiometers for setting parameters such as on-delay time, tripping delay time, current overshoot or undershoot threasholds. 3RR22 is a three-phase version with a display for setting parameters and viewing actual values and diagnostic information.



3RR22 3RR21

Current Monitoring Relays



SIMOCODE pro Motor Management System

SIMOCODE pro is an alternative approach to use of overload relays or current monitoring relays. SIMOCODE pro is a flexible, modular **motor management system** that provides multifunctional, solid-state protection for constant speed motors. SIMOCODE pro implements all motor protection and control functions; provides for tracking of operational, diagnostic, and statistical data; and communicates with the automation system via **PROFIBUS DP**.

SIMOCODE pro C is a compact, economical system for full-voltage forward and reversing starters. Each SIMOCODE pro C includes a basic unit connected by a single cable to a current measuring module. An optional operator panel may also be connected to the basic unit.

SIMOCODE pro V is a variable system with an even greater range of functions. In addition to a basic unit, it can include either a current measuring module or a combination current/voltage measuring module, up to five expansion modules, and an optional operator panel (with or without display). Expansion modules are available for discrete input/output, analog input/output, ground fault detection, and temperature sensing.



SIMOCODE pro C Motor Management System



SIMOCODE pro V Motor Management System

Review 4

1. A class ________ overload relay will trip and remove power from an overloaded motor within 10 seconds at six times full-load current.

2. A ________ overload relay, also called a ________ overload relay incorporates a small heater element wired in series with the motor and a bimetallic strip that functions as a trip lever.

3. If an overload relay trips, it can be ________ after the overload has been removed.

4. Siemens Class 48 and SIRIUS ________ thermal overload relays provide ambient temperature compensation.

5. Electronic overload relays provide overload protection without the use of ________ and can also provide ________ protection.

6. Siemens ________ electronic overload relays have DIP switches on the front for setting trip class or selecting manual or automatic reset and phase unbalance, phase loss, and ground fault detection.

7. SIRIUS ________ and ________ electronic overload relays have similar features to SIRIUS 3RB20 and 3RB30 overload relays, but allow the trip class to be set from 5 to 30 and have a ground fault detection function that can be enabled.

8. SIRIUS 3RB24 electronic overload relay has similar features to SIRIUS 3RB22/23 electronic overload relays, but has ________ communication capability.

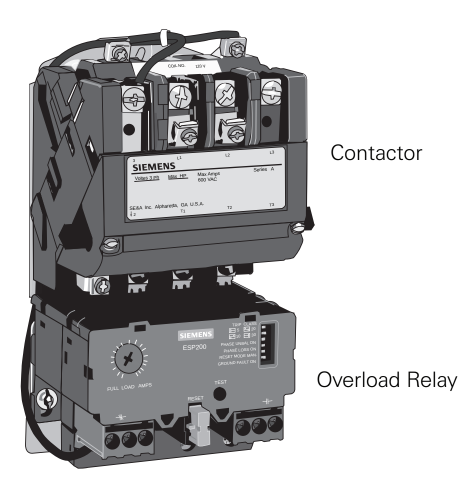
9. Although a SIRIUS ________ current monitoring relay monitors motor current and can be directly mounted to a SIRIUS 3RT2 contactor in place of an overload relay, it provides more than motor protection.

10. ________ is a flexible, modular motor management system that provides multifunctional, solid-state protection for constant speed motors.

NEMA Starters

Motor Starter

Contactors and overload relays are separate control devices. When a contactor is combined with an overload relay, it is called a **motor starter**.



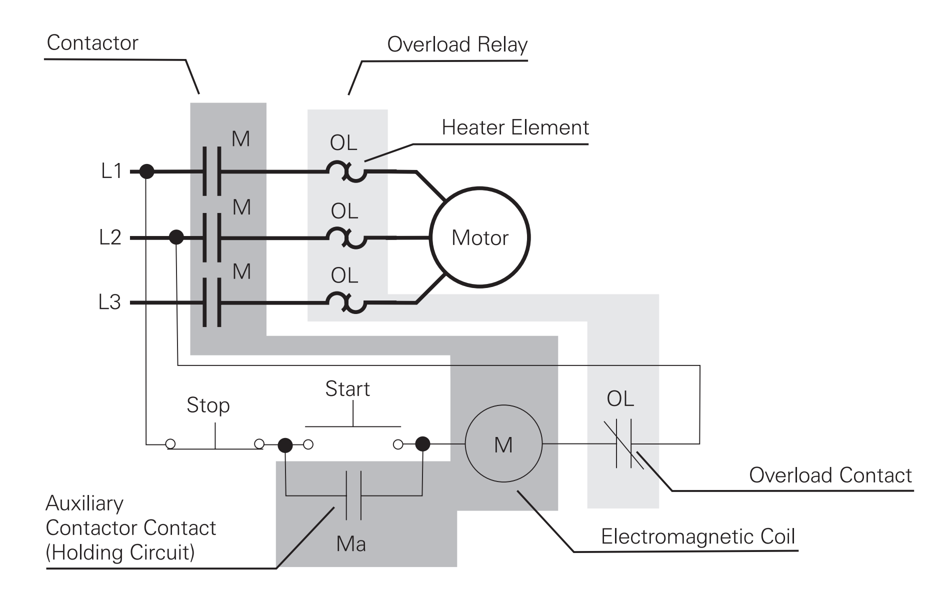
NEMA Starter

Motor starters manufactured to NEMA specifications are referred to as **NEMA starters**. Starters manufactured to IEC standards are discussed later in this course. Siemens offers both types of starters and associated components.

When a starter's contactor is set up to supply the full line voltage to a motor it is called a **full-voltage, across-the-line, or direct motor starter**.

As discussed later in this course, some starters are capable of reversing motor direction, controlling the starting voltage, or controlling two speed motors. However, the most common type of motor starter is designed to turn a motor on and off and provide overload protection. The overload relay used may be a thermal overload relay or an electronic overload relay.

The following diagram shows the electrical relationship of a contactor and an overload relay in a full-voltage motor starter circuit. The contactor (highlighted with the darker grey) includes an electromagnetic coil (M) and auxiliary contacts (Ma) in the control circuit and three main contacts (M) in the power circuit. The overload relay, highlighted by the lighter grey, includes three heaters contacts (OL) in the power circuit and auxilliary contacts (OL) in the control circuit.



In this circuit, when the Start pushbutton is pressed, power is provided to the coil, and the M contacts close. This provides power to the motor through the OL heater contacts. At the same time, Ma contacts close so that, when the Start pusbutton is released, power is still provided to the coil.

The motor continues to run until the Stop pushbutton is pressed, unless an overload occurs. If an overload occurs, the OL heater contacts open, removing power from the motor, and OL auxiliary contacts open, removing power from the coil. Removing power from the coil is necessary to prevent the motor from automatically restarting after the overload relay cools.

The **National Electrical Manufacturers Association (NEMA)** and the **International Electrotechnical Commission (IEC)** are two organizations that provide ratings for contactors, motor starters, and other types of control components. NEMA is primarily associated with equipment used in North America. IEC is associated with equipment sold in many countries worldwide, including the United States. International trade agreements, market globalization, and domestic and foreign competition have made it important to be increasingly aware of international standards.

NEMA Ratings

Contactors and motor starters are rated according to size and the type of load they are designed to handle. NEMA ratings are based on maximum horsepower ratings as specified in the NEMA ICS2 standards. NEMA starters and contactors are selected according to their NEMA size, from size 00 to size 9.

NEMA Size	Continuous Amp Rating	HP 230 VAC	HP 460 VAC
00	9	1	2
0	18	3	5
1	27	5	10
2	45	15	25
3	90	30	50
4	135	50	100
5	270	100	200
6	540	200	400
7	810	300	600
8	1215	450	900
9	2250	800	1600

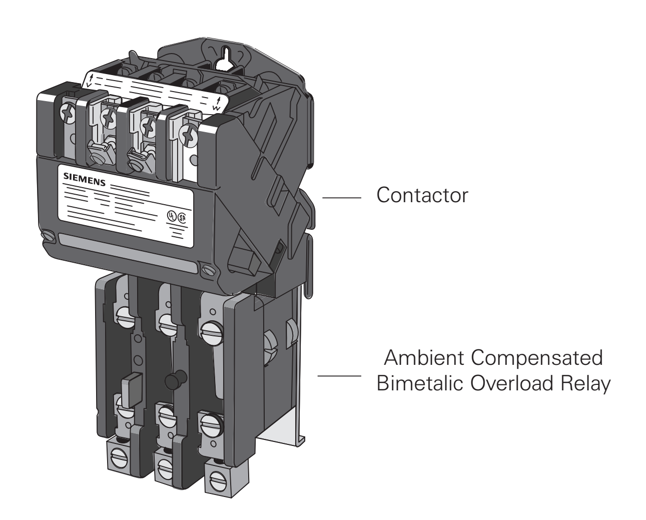
NEMA motor control devices have generally become known for their very rugged, heavy-duty construction. NEMA motor starters and contactors can be used in virtually any application at their stated rating, from simple on and off applications to more demanding applications that include plugging and jogging. To select a NEMA motor starter for a particular motor, you only need to know the horsepower and voltage of the motor. However, if there is considerable plugging and jogging duty involved, even a NEMA-rated device will require some derating.

Siemens also has what are called **Motor Matched sizes** available on some Siemens motor starters. The ratings for these devices fall in between the ratings of normal NEMA sizes, allowing the user to more closely match the motor control to the actual application. Motor Matched sizes are beneficial because they cost less than larger NEMA size starters. The following table shows the Motor Matched sizes available.

MM Size	Continuous Amp Rating	HP 230 VAC	HP 460 VAC
1¾	40	10	15
2½	60	20	30
3½	115	40	75

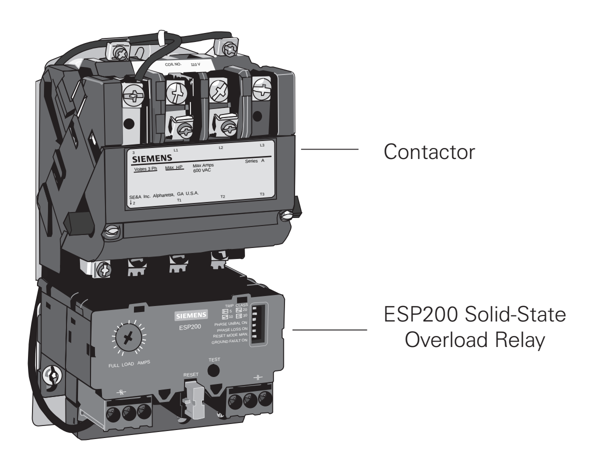
Class 14 NEMA Starters

Class 14 NEMA starters with ambient-compensated bimetal overload relays are available up to 100 HP at 460 VAC (NEMA sizes 00 through 4). In addition to whole sizes, this range includes 1¾, 2½, and 3½ sizes. These starters are available with class 10 or 20 ambient-compensated bimetal overload relays.



Class 14 ESP200 starters use the same contactors as Class 14 NEMA starters equipped with bimetal overload relays (for NEMA sizes 00 through 4), but are supplied with an ESP200 solid-state overload relay. In addition, these starters are available with contactors up to and including NEMA size 8.

The ESP200 overload relay provides users with the specific level of protection they desire. For example, the trip class (5, 10, 20, or 30) is set using DIP switches on the front of the unit and the full-load ampere (FLA) dial allows for a wide range (4:1) of adjustment.

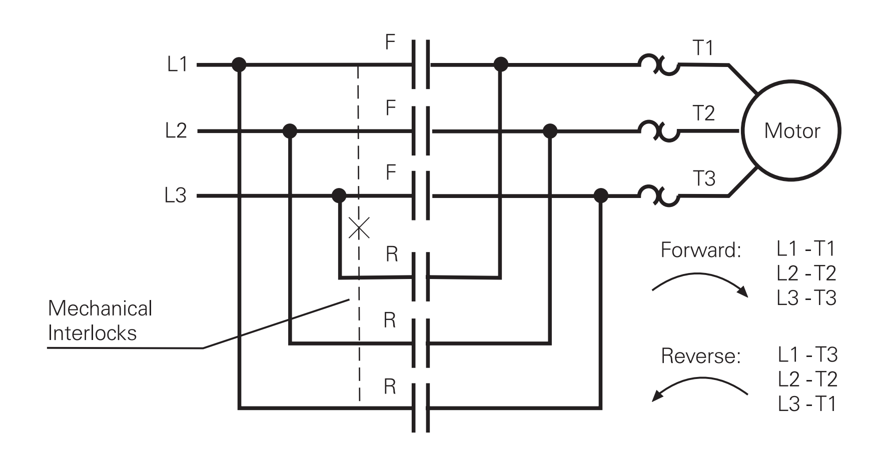


As previously mentioned, 958 and 958L ESP200 solid state overload relays are also available for specialized applications.

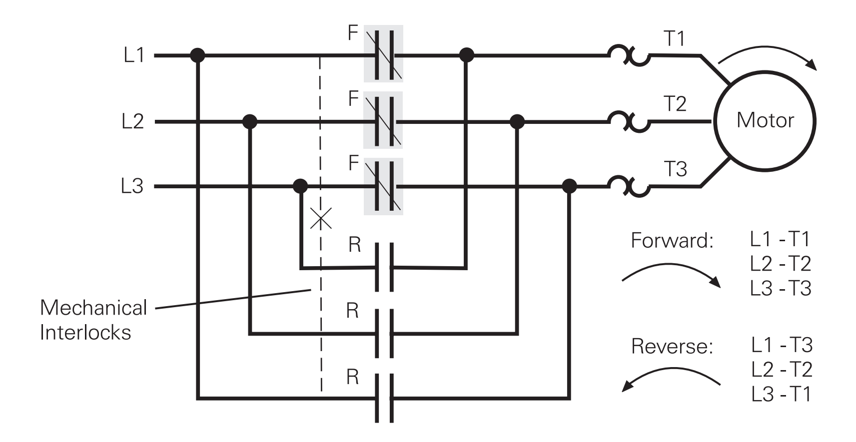
Reversing Starters

Many applications require a motor to run in either direction, forward or reverse. The direction of motor rotation is changed by changing the direction of current flow through the windings. This is done for a three-phase motor by reversing any two of the three motor leads. Most often, T1 and T3 are reversed.

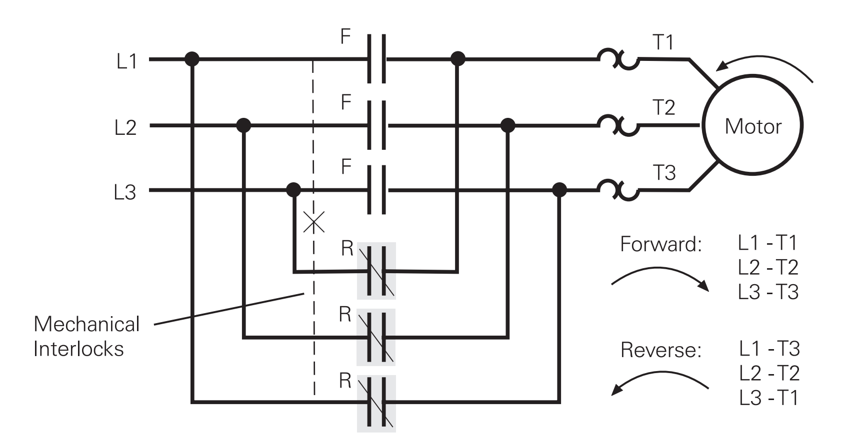
The following illustration shows a three-phase motor **reversing circuit** with one set of forward (F) contacts controlled by the "F" contactor and one set of reverse (R) contacts controlled by the "R" contactor.



When the “F” contacts close, current flows through the motor causing it to turn in a clockwise direction.



When the “F” contacts open and the “R” contacts close, current flows through the motor in the opposite direction, causing it to rotate in a counterclockwise direction. Mechanical interlocks prevent both forward and reverse circuits from being energized at the same time.



Siemens offers **Class 22 reversing starters** in NEMA sizes 00 through 8 including Siemens half-sizes. Both ESP100 solid-state and ambient-compensated bimetal overload relays are available.

Siemens offers **Class 43 reversing contactors** in NEMA sizes 00 through 8, including Siemens half-sizes.

Siemens also offers IEC reversing starters as described later in this course.

Two-Speed Heavy Duty Starters

The synchronous speed of a three-phase induction motor is a function of the supply frequency and the number of poles. This speed is the rate in RPMs for the motor's rotating magnetic field.

$$\text{Synchronous Speed in RPM} = \frac{120 \text{ x Fequency}}{\text{Number or Poles}}$$

For example, a motor with four poles on a 60 hertz AC line has a synchronous speed of 1800 RPM.

$$\text{Synchronous Speed} = \frac{120 \text{ x } 60 \text{ Hz.}}{4} = 1800 \text{ RPM}$$

For a three-phase induction motor, actual rotor speed is always less than synchronous speed due to **slip**. The design of the motor and the amount of load applied determine the percentage of slip. For example, a NEMA B motor with a synchronous speed of 1800 RPM will typically have a full-load speed of 1650 to 1750 RPM.

When motors are required to run at different speeds, the motor's characteristics vary with speed. Therefore, proper motor selection and application is critical. There are three categories of multi-speed applications: constant torque, variable torque, and constant horsepower.

Constant Torque (CT) applications require constant torque at all speeds. Horsepower varies directly with speed. For example, many conveyor applications require constant torque.

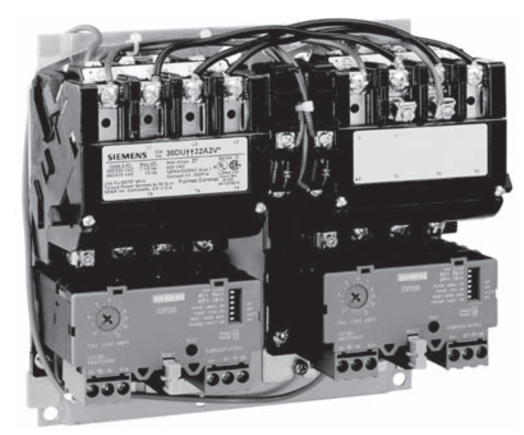
Variable Torque (VT) applications often have load torques proportional to the square of the speed. Fans, blowers, and centrifugal pumps are examples of variable torque applications.

Constant Horsepower (CHP) applications maintain constant horsepower at all speeds, with torque varying inversely with speed. Many metal-working machines such as drills, lathes, mills, bending machines, punch presses, and power wrenches are examples of constant horsepower applications.

Two types of induction motors that provide for two-speed control using magnetic starters are **separate winding motors** and **consequent pole motors**. Consequent pole motors with two speeds on a single winding require a starter which reconnects the motor leads to half the number of effective motor poles for high speed operation. For this type of motor, the low speed is one half the high speed.

Separate winding motors have a winding for each speed and provide more varied speed combinations because the low speed need not be one half the high speed. Starters for separate winding motors consist of a starter unit for each speed.

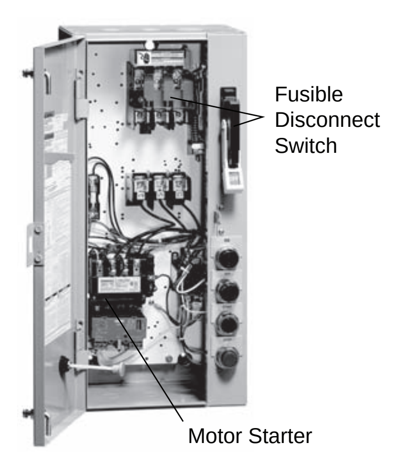
Siemens offers **Class 30 two-speed heavy duty starters** for separate-winding and consequent-pole motors used in constant torque, variable torque, and constant horsepower applications. Starters are available in NEMA sizes 0 through 4, including Siemens Motor Matched sizes. Overload protection is furnished either with ESP200 electronic overload relays or ambient-compensated thermal overload relays. Siemens also offers Class 32 combination two speed heavy duty starters.



Two Speed Heavy Duty Starter
with ESP200 Electronic Overload Relays

Combination Starters

Combination starters incorporate a motor starter, short circuit protection, and a means to safely disconnect power. Siemens offers a variety of enclosed combination starters and non-combination starters with NEMA components in a full range of enclosure types.



Class 17 Combination Starter
in Type 1 Enclosure

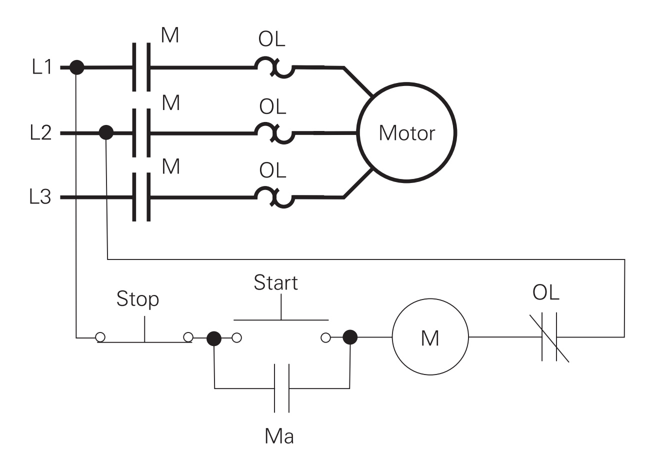


NEMA Enclosed Starters

Duplex motor controllers consist of two motor starters in a common enclosure. Siemens duplex motor controllers are specifically designed for industrial and commercial applications that require duplex controls such as duel pumps or blowers. Siemens **Class 83** is a **non-combination duplex motor controller**. Siemens **Class 84** is a **combination duplex motor controller** with two separate disconnects or circuit breakers.

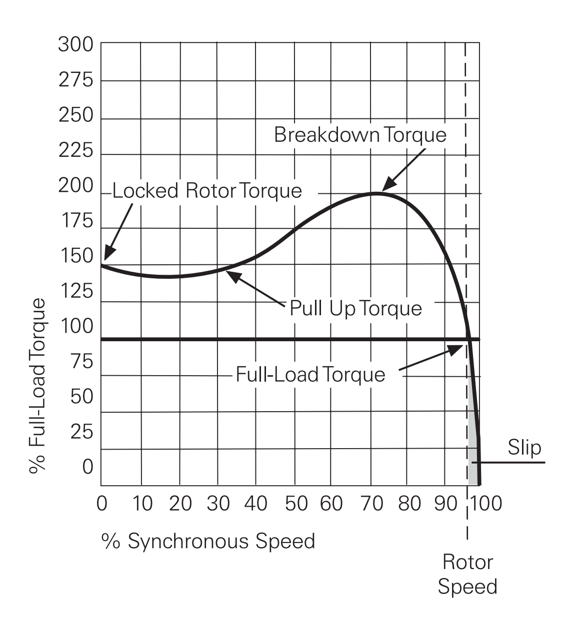
Full-Voltage Starting

The motor starters discussed thus far have all been full-voltage starters. This is the most common type of motor starter because the initial component cost is low. A full-voltage starter is also referred to an as across-the-line starter because it starts the motor by applying the full line voltage.



When a motor is started with full voltage, starting current can be as high as 600% of full-load current for a standard three-phase induction motors and as high as 1200% of full-load current for high efficiency motors. This high starting current causes power fluctuations that affect other equipment. As a result, many power companies require reduced-voltage starting for large-horsepower motors.

Another potential problem with full-voltage starting is the high torque developed when power is first applied to the motor. As shown in the speed-torque curve for a NEMA B motor, the initial torque, also called locked rotor torque, is typically around 150 percent of full-load torque. Additionally, the torque can rise as high as 175 to 200 percent of full-load torque as the motor accelerates to rated speed.



Many applications require the starting torque to be applied gradually. For example, a belt-type conveyor application often requires the starting torque to be applied gradually to prevent belt slipping and bunching. Also, in any application that involves frequent starts, the higher initial starting torque, over time, results in higher maintenance costs due to repeated mechanical shock.

Reduced-Voltage Starting

As the name implies, **reduced-voltage starting** involves starting a motor at less than its full voltage rating and then increasing the voltage as the motor comes up to speed. Reduced-voltage starting is used when it is necessary to limit the starting current and/or starting torque of a motor. Several methods are available for reduced-voltage starting.

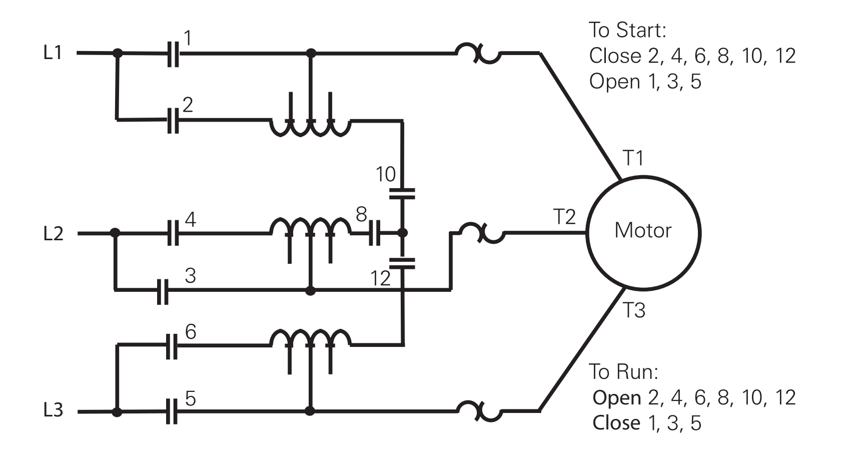
Siemens offers the following types of reduced-voltage starters with NEMA components: **autotransformer starters**, **part-winding starters**, and **wye-delta starters**. Siemens also offers wye-delta starters and soft starters with IEC components as described later in this course.

Autotransformer Starters

One of the more basic types of reduce-voltage starters is the **autotransformer reduced voltage starter**. Autotransformer reduced-voltage starters provide a high starting torque per ampere of line current and are typically used for applications where starting current must be reduced while retaining good starting torque.

Autotransformers have adjustable taps to set the reduced starting voltage as a percentage of the full-line voltage.

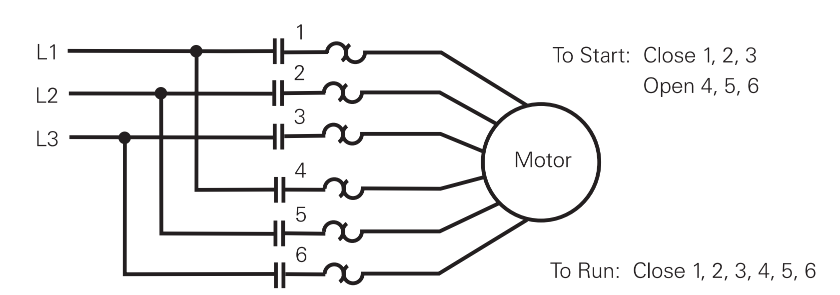
Common applications for autotransformer reduced-voltage starters include: crushers, fans, conveyors, compressors, and mixers



Siemens offers autotransformer starters as **Class 36 non-combination starters** and **Class 37 combination starters** with a fusible or non-fusible disconnect or circuit breaker.

Part-Winding Starters

Part-winding reduced-voltage starters are used with motors which have two separate parallel windings on the stator. One magnetic starter engages the first set of windings when the motor is started. These windings draw about 65 to 85% of the rated locked rotor current. After a set time, a second magnetic starter energizes and places the second set of windings in parallel with the first.



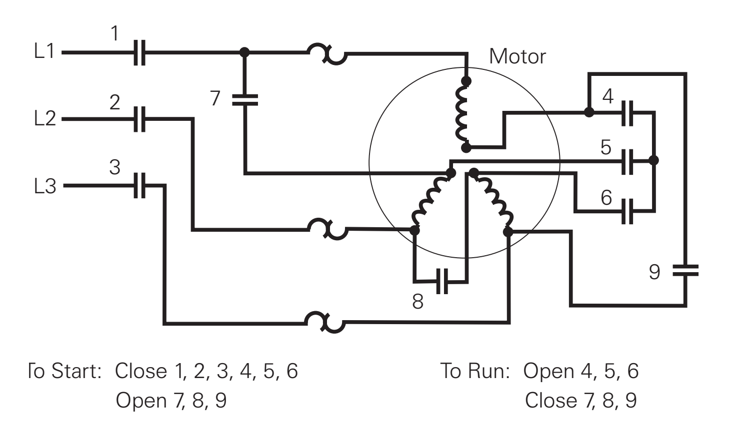
Part winding reduced-voltage starters are the least expensive type of reduced-voltage starters and use a simplified control circuit. However, they require a special motor design, are not suitable for high-inertia loads, and do not have adjustments for current or torque.

Siemens offers part winding starters as **Class 36 non-combination starters** and **Class 37 combination starters** with a fusible or non-fusible disconnect or circuit breaker.

Wye-Delta Starters

Wye-delta reduced voltage starters are applicable only for motors with stator windings not connected internally and all six motor leads available for external connections.

Connected in a wye configuration, the motor starts with a significantly lower inrush current than if the motor windings had been connected in a delta configuration. After a set time, starter contacts change state to connect the stator windings in a delta configuration. This increases the voltage applied across each stator winding.



This type of starter is a good choice for applications that require frequent starts, low starting torque, or long accelerating times.

Siemens offers wye-delta starters as **Class 36 non-combination starters** and **Class 37 combination starters** with a fusible or non-fusible disconnect or circuit breaker.

Pump Control Panels

Pump controllers monitor flow and/or level variables and control a pump to maintain the desired values. Pump control can involve simply turning a pump on and off or can include more advanced controls for pump speed, output pressure, etc.

Siemens pump control panels are factory wired to simplify installation, provide flexible control, and protect against short circuits and overloads. Ample space is provided for field modifications and installation of accessories.

Siemens offers pump control panels as **Class 87 full voltage and vacuum starters** as well as **Class 88 autotransformer starters, part-winding starters,** and **wye-delta starters**.



Review 5

1. When a contactor is combined with an overload relay, it is called a ________.

2. ________ and ________ are two organizations that provide ratings for control components.

3. A NEMA size ________ contactor is rated for 200 HP at 460 VAC.

4. A Siemens Motor Matched Size $2\frac{1}{2}$ contactor is rated for ________ HP at 230 VAC.

5. A reversing starter reverses motor direction by switching ________ motor leads.

6. Siemens offers Class 30 two-speed heavy duty starters for ________ and ________ motors.

7. ________ starters incorporate a motor starter, short-circuit protection, and a means to safely disconnect power.

8. ________ reduced voltage starters are applicable only for motors with stator windings not connected internally and all six leads available for external connections.

IEC Starters

SIRIUS Modular System

The SIRIUS modular system includes a complete range of industrial control components designed to IEC specifications for use in switching, starting, protecting, and monitoring of systems and motors. Examples of some of these components are shown in the following graphic, which displays a structured range of motor starters, MSPs, contactors, and overload relays in seven compact frame sizes. These frame sizes are referred to as S00, S0, S2, S3, S6, S10, and S12. SIRIUS Innovations additions to the SIRIUS system, shown outlined in black in the following graphic, further enhance the capabilities of this system.

Size	S00	S0	S2	S3	S6	S10	S12
Communication-capable Motor Starters							
Motor Starters							
Motor Starter Protectors							
Contactors							
Thermal Overload Relays						Vacuum	
Electronic Overload Relays							
Soft Starters							

A feature of the SIRIUS system is the narrow mounting width. Along with the ability of SIRIUS components to operate at ambient temperatures up to 140° F (60° C), this allows more units to be packed into a panel without overheating the components.

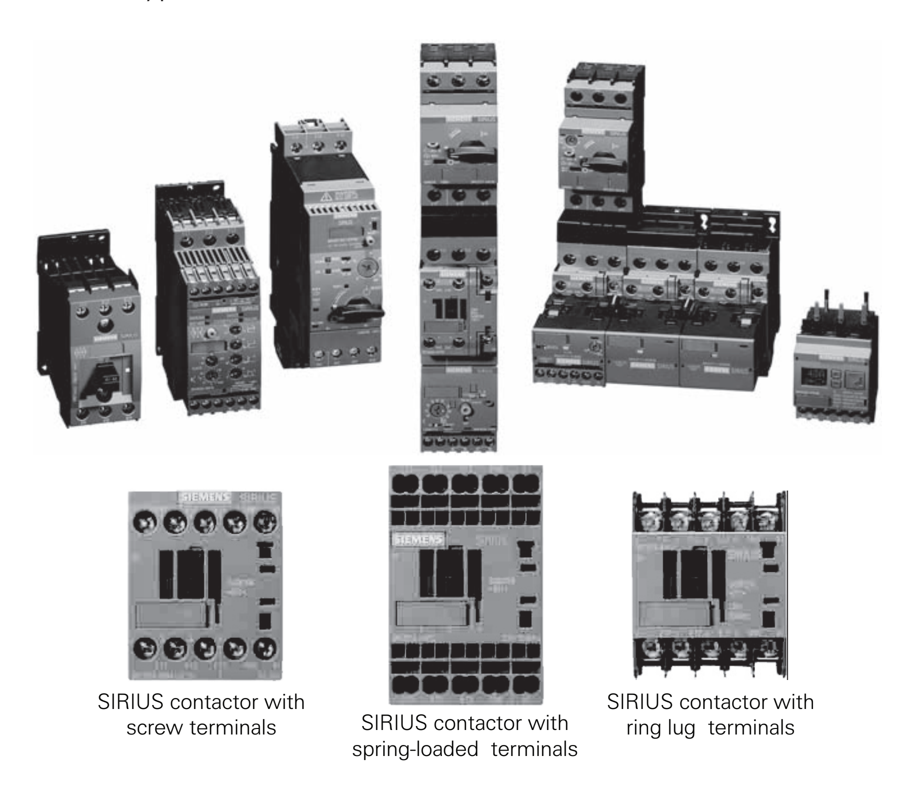
Among the many additional advantages of the SIRIUS system is the significant reduction in wiring cost made possible by plug-in connections and the use of IO-Link or AS-Interface communications.

SIRIUS Innovations

The SIRIUS Innovations additions to the SIRIUS modular system result from a complete redesign of size S00 and S0 components, which extends the continuous current range (up to 40 A for S0) while maintaining a 45 mm footprint.

This redesign incorporated many features which reduce heat generation, required panel space, and the time required to configure, assemble, and test a control system. One example of the many time saving system enhancements is the increased use of spring-loaded terminals in both the power and control circuits. In addition to reducing assembly time, these spring-loaded terminals provide gas-tight connections resistant to shock and vibration.

While spring-loaded terminals are desired by many customers, some customers prefer screw terminals. In addition, customers purchasing components for railway and oil and gas applications often require ring lug terminals. As a result, many SIRIUS Innovations components are available with any of these three terminal types.



SIRIUS contactor with screw terminals

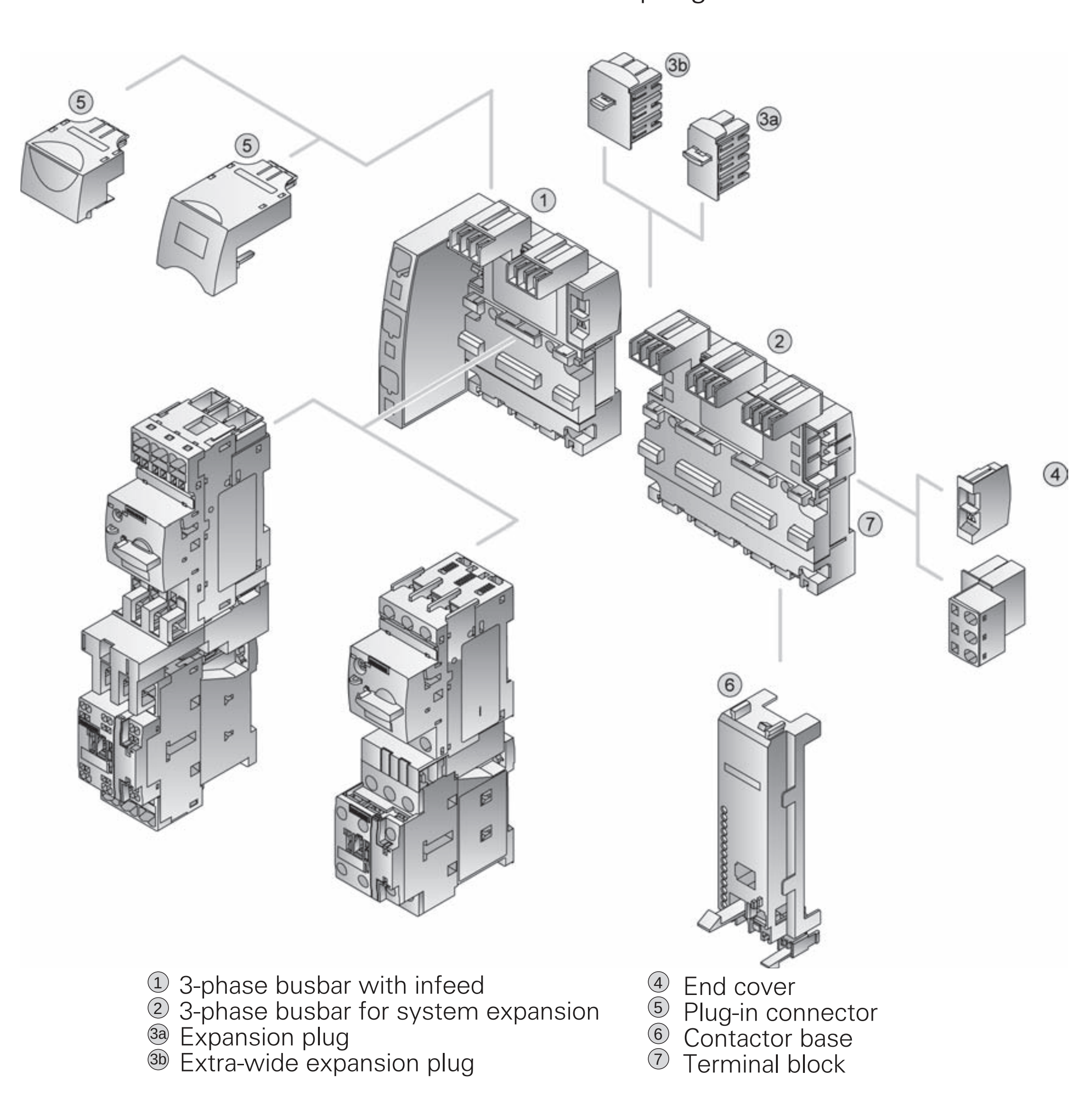
SIRIUS contactor with spring-loaded terminals

SIRIUS contactor with ring lug terminals

Easy Assembly

The SIRIUS modular system is a flexible system of electrically and mechanically matched components that can be easily assembled to create load feeders. In addition, pre-assembled load feeders are also available.

For example, the following graphic shows SIRIUS components being assembled using the **3RV29 infeed system**. Both the 3RV29 infeed system and 3RA6 infeed system (shown later) are available with either screw or spring-loaded terminals.



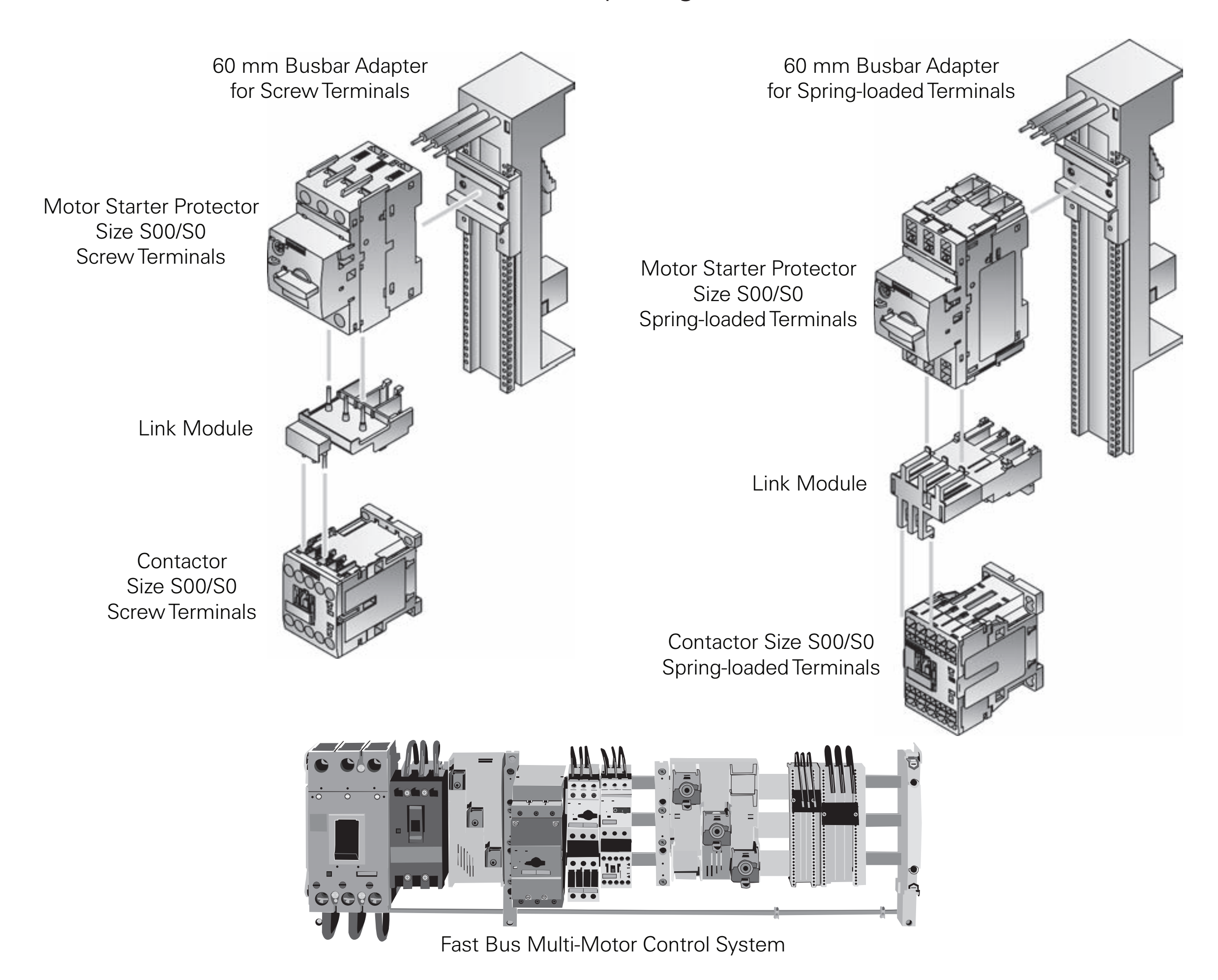
To further simplify assembly, Siemens also offers SIRIUS 3RA2 pre-assembled starters (with screw terminals only) and SIRIUS 3RA6 compact starters.

Fast Bus Multi-Motor Control System

Additional approaches applicable for control panels include busbar adapters for use with Siemens **Fast Bus Multi-Motor Control System**.

Fast Bus is a three-phase, insulated busbar system that reduces wire connections and hole drilling when building control panels.

Fast Bus is not new to Siemens, but due to the narrow dimensions of SIRIUS components, more starters can fit on the same run of Fast Bus. Components are available for busbar center-line spacings of 60 mm.



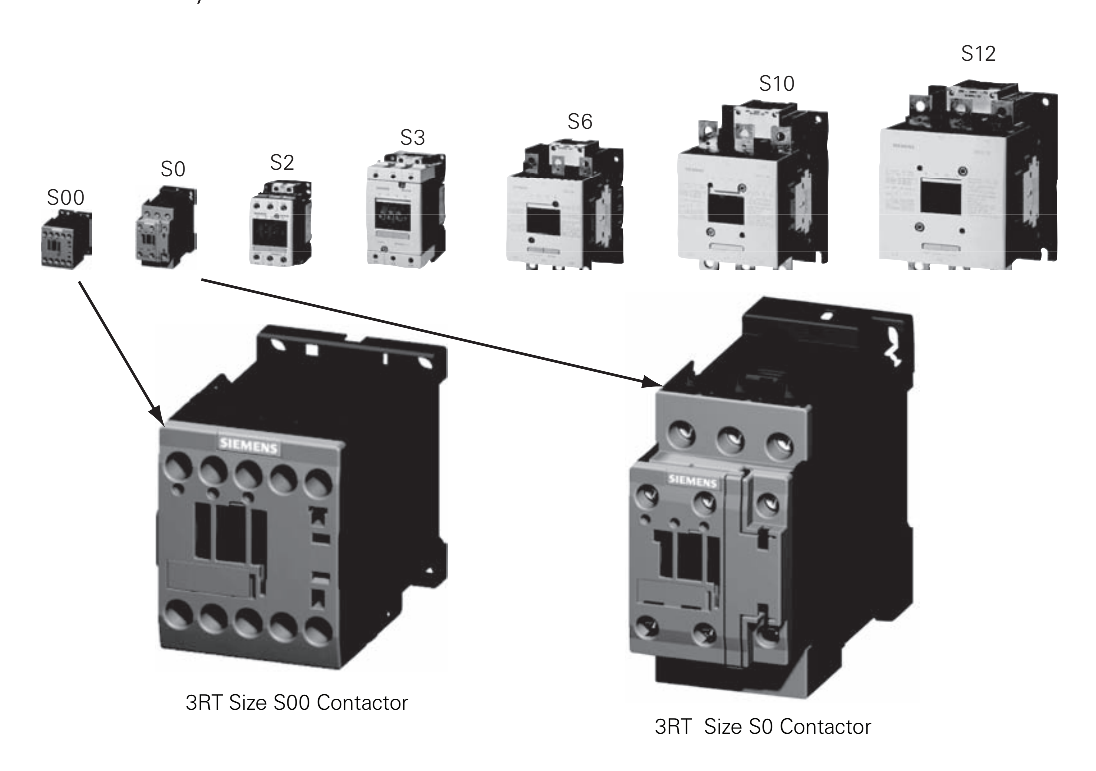
Fast Bus Multi-Motor Control System

In addition to assembly systems for use in control panels, SIRIUS communication options make distributed control easier to implement as well.

SIRIUS Contactors for Motor Loads

The SIRIUS modular system includes a wide range of power contactors in sizes S00 to S12 for switching motors. In addition to 3-pole standard contactors, vacuum contactors, coupling relays for optimal interfacing with the outputs of controllers, various 4-pole power relays and miniature contactors are also available.

3RT2 contactors are part of the SIRIUS Innovations addition to the SIRIUS modular system and are available in sizes S00 and S0. In addition to being used in full-voltage, non-reversing starters, they can be easily configured for use in reversing or wye-delta starters.



3RT Size S00 Contactor

3RT Size S0 Contactor

Auxiliary contacts can be side mounted on all contactors or a front-mounted contact block can be used. Communication function modules are also available for use with 3RT2 S0 and S00 contactors.

In addition to AC and DC powered versions, an **electronic UC coil version** of the 3RT2 S0 contactor is available. The UC contactor version can be controlled using either AC or DC voltage with much lower power consumption. 3RT2 S0 contactors also have a number of features that make wiring simpler and neater. In addition to the optional communication function modules, this includes front coil terminals, two integrated auxiliary contacts (one normally open and one normally closed), and a control wiring duct door for routing of control wires or inserting surge protection accessories.

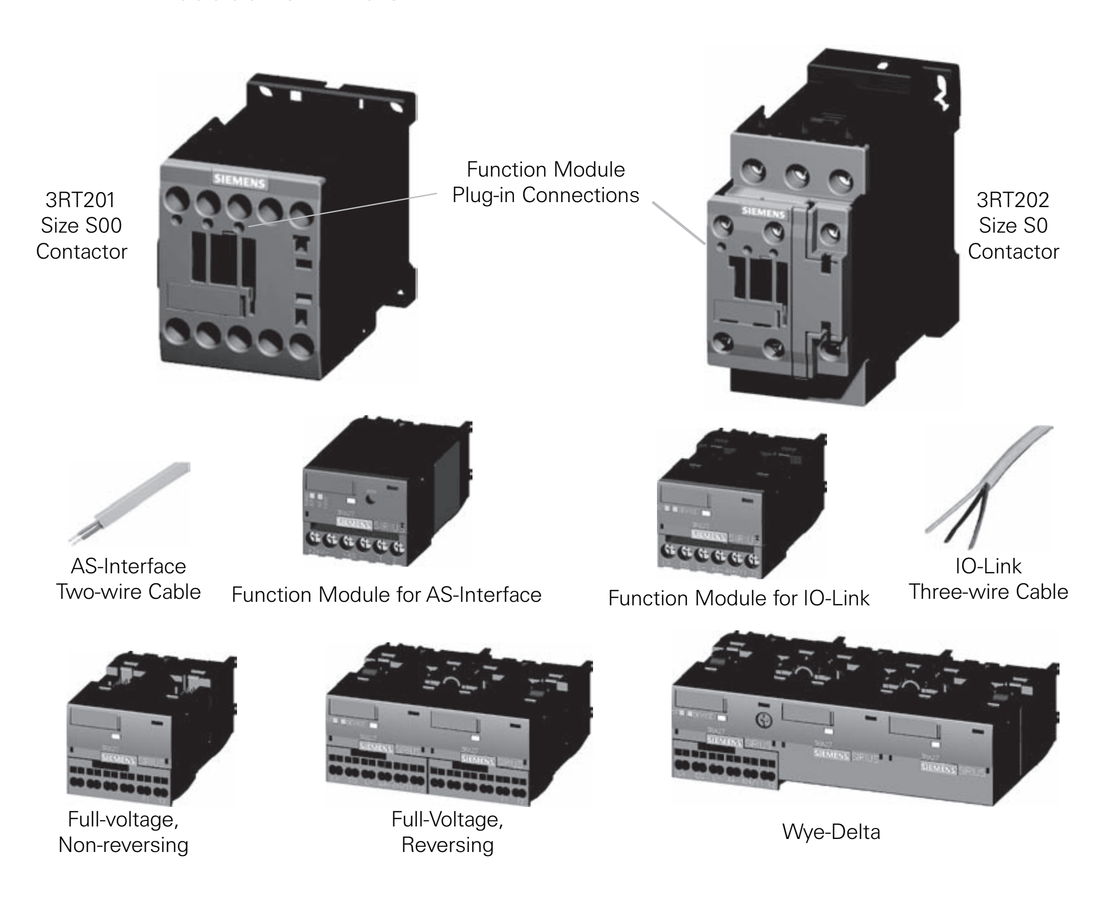
S00 and S0 Contactor Function Modules

Plug-in function modules are available for selected versions of 3RT2 contactors to reduce the control circuit wiring when assembling full-voltage, non-reversing; full-voltage, reversing; and wye-delta starters.

Function modules for full-voltage, non-reversing starters support time-delayed opening/closing of the contactor. Mechanical and electrical interlocking is integrated for a reversing starter assembly. For a wye-delta assembly, use of function modules instead of complex wiring results in a 70 percent reduction in wiring in the control circuit and a smaller footprint because the timing relay and the coil protection circuit are integrated.

These function modules with starter functions are also available with connections for AS-Interface or IO-Link communication. In addition to the reduction in wiring within the branches, interfacing to PLCs is greatly simplified and fewer PLC I/O modules are needed. This approach also facilitates plant-wide diagnostics down to the contactor level.

These function modules can be used with either the S00 or S0 size contactor and are available with screw-type or spring-loaded terminals.



Solid State Contactors for Motor Loads

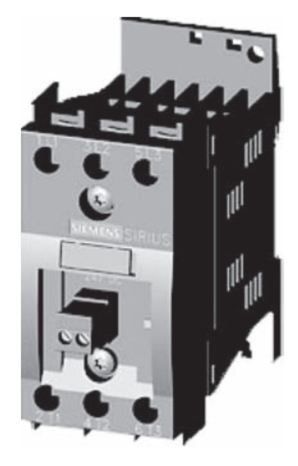
Some applications require rapid switching of small, 3-phase motors. For example, conveyor technology or palletizing machines may require rapid motor switching to satisfy the demands of high-speed material handling systems. In such cases, electromechanical contactors may be either unable to switch fast enough or unreliable for prolonged use.

SIRIUS 3RF2 solid state contactors and **reversing contactors for motor loads** are designed to satisfy the demands of these rapid switching applications. In addition, they switch quietly and are therefore suitable for noise-sensitive environments.

3RF2 solid state contactors and reversing contactors are two-phase controlled with instantaneous switching. They are embedded in an insulated housing with a width of 45 mm or 90 mm. For reversing starters, this provides a substantial reduction in mounting width over comparable electromechanical contactors.

3RF2 solid state contactors and reversing contactors are available with screw type or spring loaded terminals. As part of the SIRIUS modular system, they can be easily integrated into motor feeders employing other SIRIUS components.

3RF2 solid state contactors for motor loads are rated up to 5.2 A in a width of 45 mm and up to 16 A in a width of 90 mm, allowing motors up to 10 HP (7.5 kW) to be controlled. 3RF2 solid state reversing contactors with a width of 45 mm can switch motors up to 3 HP (2.2 kW) and the 90 mm width design can switch motors up to 4 HP (3 kW).



SIRIUS 3RF2 Solid State Contactor for Motor Loads



SIRIUS 3RF2 Solid State Reversing Contactor for Motor Loads

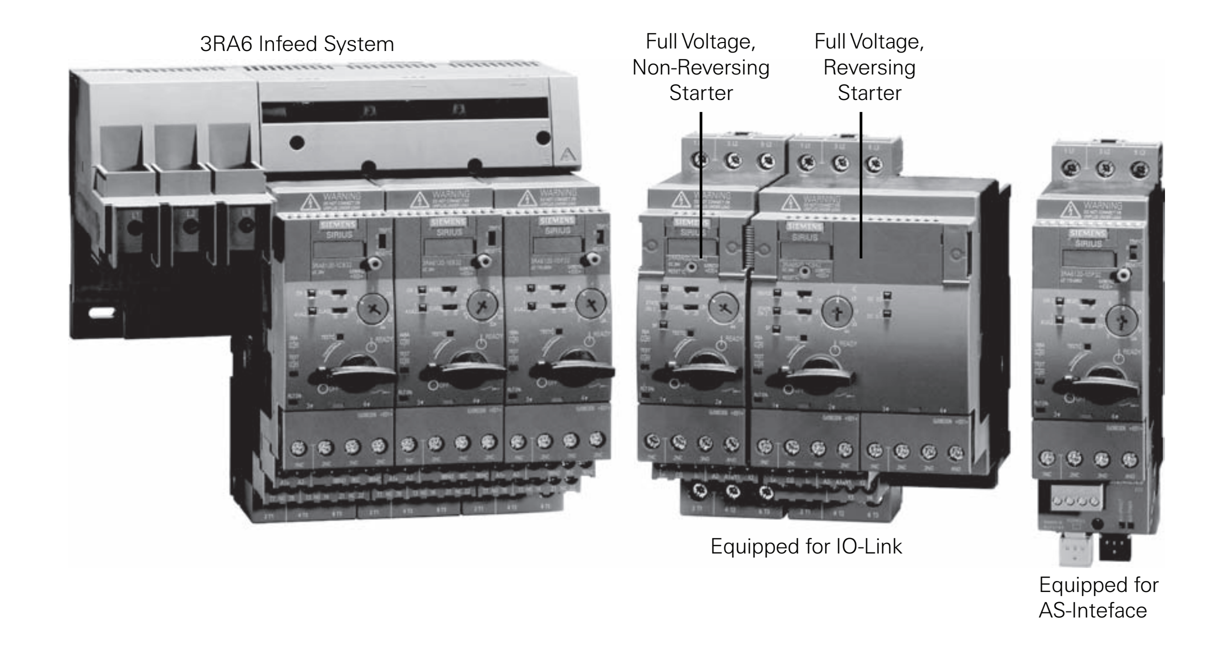
Compact Starters

SIRIUS 3RA6 compact starters incorporate a motor starter protector, contactor, electronic overload relay, and all the typical accessories in one unit for reduced panel space, installation cost, and a significant reduction in power dissipation.

Trip class 10 or 20 and automatic or manual reset are selectable along with a wide range of motor current settings. Auxiliary contacts for signaling an overload or short circuit are integrated into the design. An end of service life indicator provides advance warning of the need for starter replacement and removable terminals allow for quick device changes.

Four mounting options are available: parallel wiring (DIN or surface mounted), comb bus bar (DIN or surface mounted), 3RA6 infeed system (up to 100 A), and Fast Bus.

SIRIUS 3RA6 compact starters can be equipped for IO-Link or AS-Interface communication.

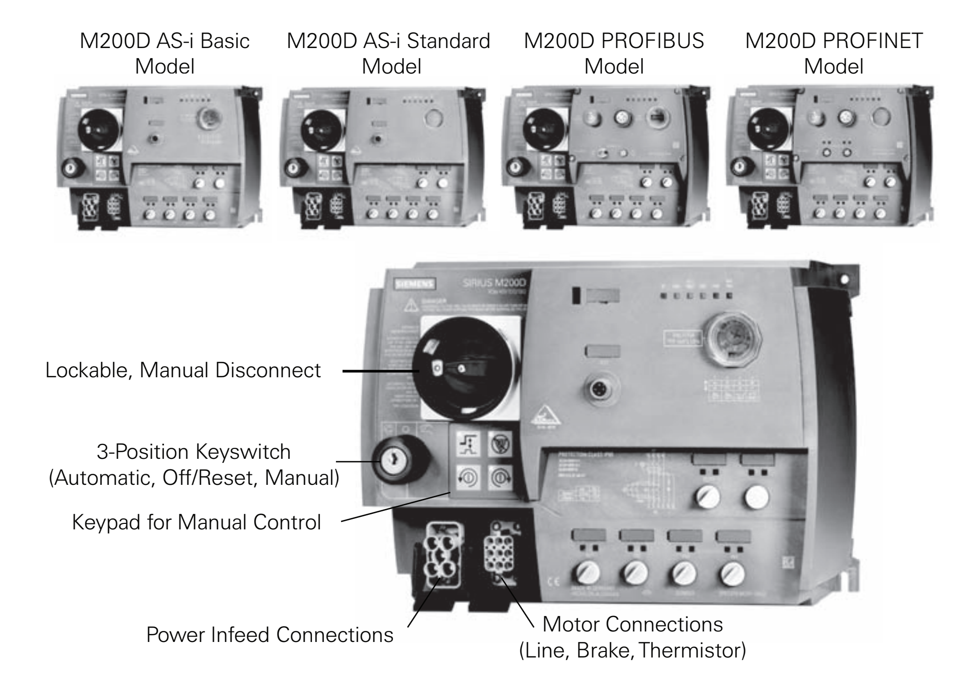


Enclosed Starters with Communication

SIRIUS **M200D** is an **enclosed** (IP65 rated) **motor starter** with communication capability that is ideally suited for distributed motor control applications such as material handling or packaging. Four models of M200D starters are available. Two models (Basic and Standard) work with AS-Interface (AS-i). One of the remaining models works with PROFIBUS DP and the other works with PROFINET.

MD200D starters come in two current ranges (0.15 to 2 A and 1.5 to 12 A) with a maximum of 7.5 HP. All models include a lockable manual disconnect, short-circuit and overload protection, and connections for a thermistor to sense motor temperature.

Optional selections include mechanical or electronic switching, full-voltage non-reversing or reversing operation, and with or without local control. The electronic switching versions of all models, except AS-Interface Basic, are available with soft starter functionality.



SIRIUS Soft Starters

Solid state, reduced-voltage starters, often called **soft starters**, limit motor starting current and torque by ramping up the voltage applied to the motor during the selectable starting time. Soft starters accomplish this by gradually increasing the portion of the power supply cycle applied to the motor windings, a process sometimes referred to as **phase control**.

Once the start up has completed, SIRIUS soft starters use integrated bypass contacts to bypass power switching devices (thyristors). This improves efficiency, minimizes heat, and reduces stress on these switching devices.

Some soft starters (such as SIRIUS 3RW40 and 3RW44) also allow the phase control process to be applied in reverse when the motor is being stopped. This controlled starting and stopping significantly reduces stress on connected devices and minimizes line voltage fluctuations.

The SIRIUS modular system includes SIRIUS **3RW30** and **3RW40** soft starters for standard applications and SIRIUS **3RW44** soft starters for high feature applications.

SIRIUS 3RW30 and 3RW40 Soft Starters

SIRIUS 3RW30 soft starters have an especially compact design that saves space and easily integrates with other SIRIUS components. 3RW30 soft starters are available for supply voltages up to 480 VAC and operating current up to 106 A at 40° C. Potentiometers on the front of the unit provide settings for ramp-up time and starting voltage.

SIRIUS 3RW40 soft starters have all the advantages of 3RW30 soft starters, but have more features and are available for operating current up to 432 A at 40° C. Features include: selectable motor overload protection (Class 10, 15, 20), manual or remote reset, and optional thermistor motor protection. 3RW40 soft starters are also equipped with integrated intrinsic device protection to prevent thermal overloading of the power switching devices (thyristors). Potentiometers on the front of the unit provide settings for current limit, starting voltage, and ramp-up and ramp-down times.



3RW30 Soft Starters

3RW40 Soft Starters

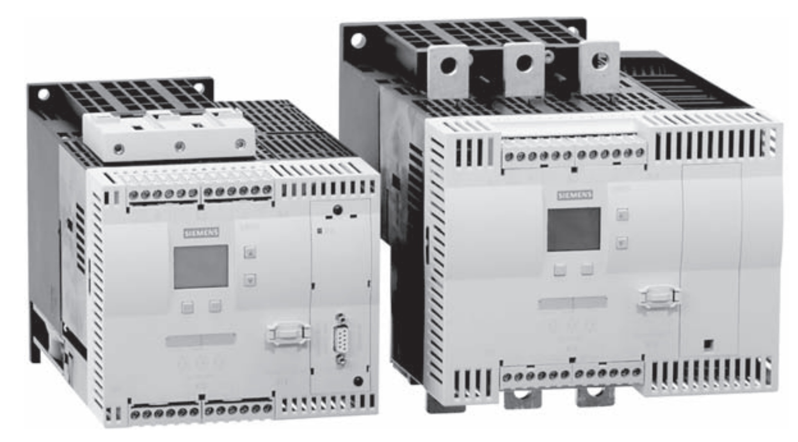
SIRIUS 3RW44 Soft Starters

SIRIUS 3RW44 soft starters make soft starting and stopping attractive for demanding applications and combine a high degree of functionality and extensive diagnostics. 3RW44 soft starters are available for operating current up to 1214 A at 40° C.

A backlit display with 4-key operation simplifies the process of changing parameters. An RS-232 serial interface is provided to communicate with the Soft Starter ES software for easy configuration or a display for external operation and monitoring.

Additional features include, but are not limited to:

- Motor overload and thermistor protection
- Selectable current limiting
- Multiple starting and stopping/braking modes
- Intrinsic device protection for thyristors
- Optional PROFIBUS DP communication



3RW44 Soft Starters

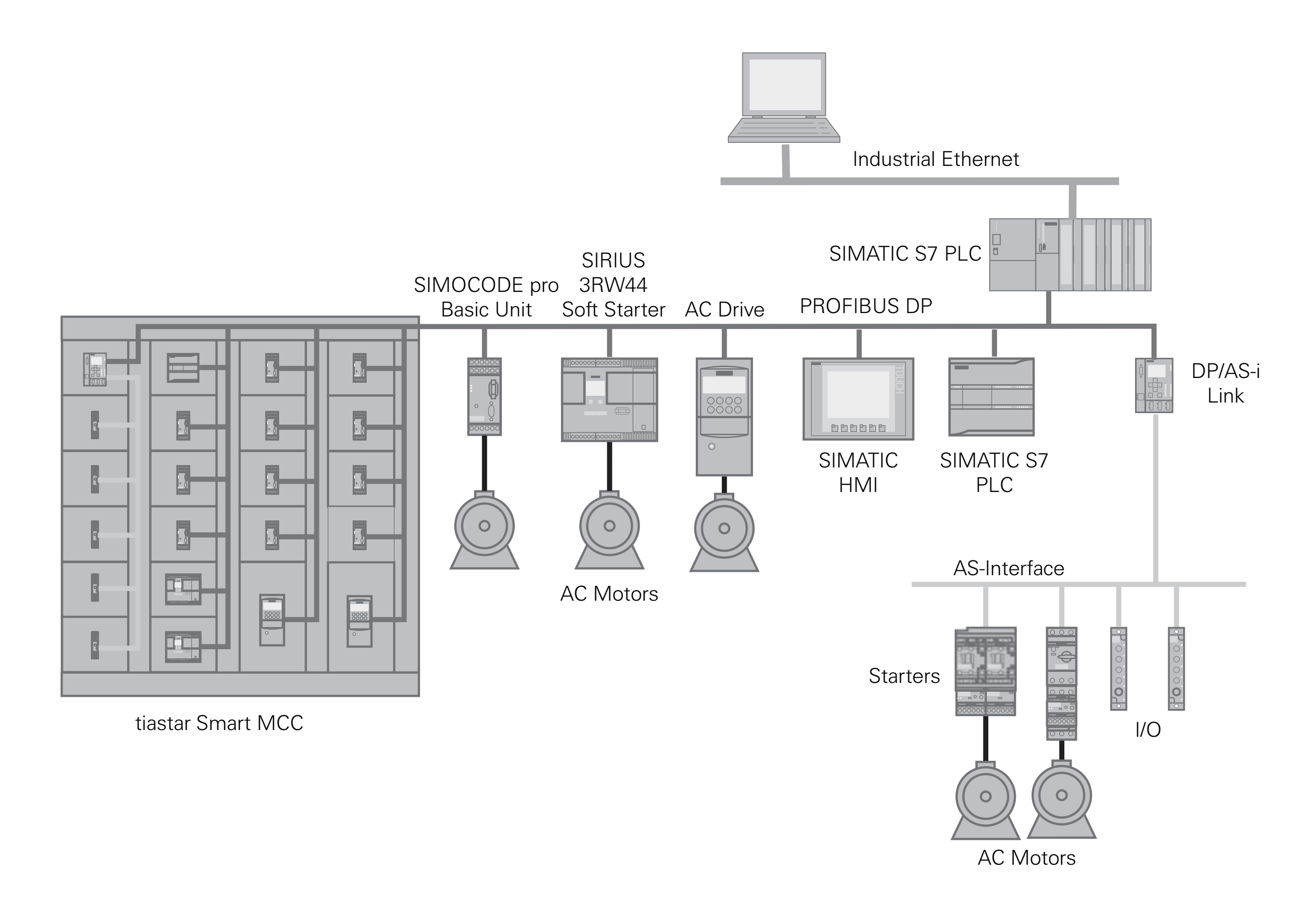
PROFIBUS DP and AS-Interface

Over time, a number of networks have been developed for use in industrial applications. Some of these networks, like Industrial Ethernet or PROFINET, are intended for higher level communication, and others are designed for control applications. A network intended to interconnect distributed control devices is often referred to as a field bus.

Field buses, like **PROFIBUS DP** and **Actuator-Sensor Interface** (**AS-Interface** or **AS-i**), provide efficient communication enabling the use of distributed intelligence.

PROFIBUS DP is an open network that has been adopted by many equipment suppliers. With regard to Siemens products, PROFIBUS DP is used internal to a tiastar Smart MCC and is also used to link many products and systems such as SIMOCODE pro C and V motor management systems, SIRIUS 3RW44 soft starters, and SIMATIC PLCs.

AS-Interface is an open, low-cost network endorsed by the AS-International Association that simplifies the interconnection of actuators and sensors with controllers. AS-Interface replaces the complex wiring and proprietary interfaces often used for this interconnection with only two wires which transfer both data and power.



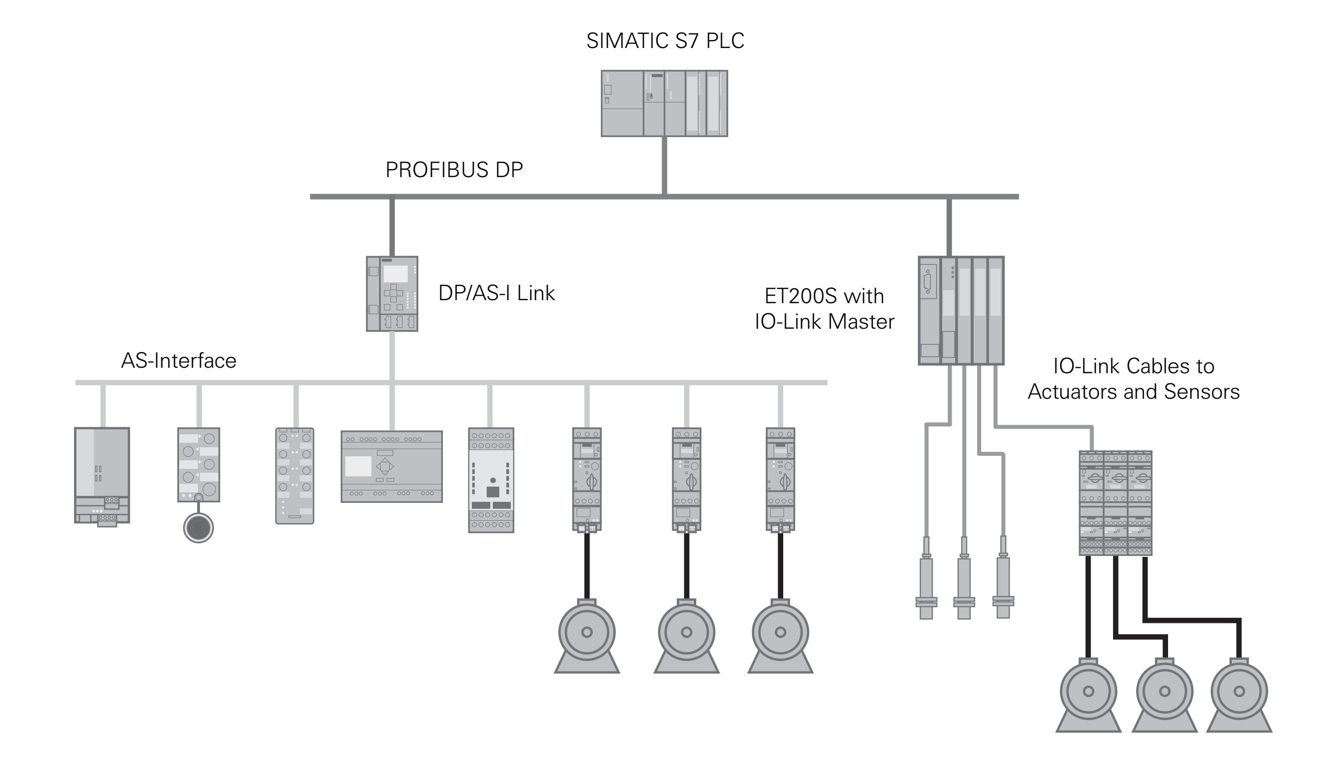
AS-Interface and IO-Link

AS-Interface allows actuators and sensors distributed throughout a system to communicate with an AS-i master, and through the master to other devices or networks. Each section of an AS-i bus includes the AS-i master, an AS-i power supply and up to 62 slave devices over a 100 meter, two-wire cable. The length of the cable can be extended to 200 meters with an extension plug or repeater and up to a maximum of 600 meters with two repeaters and an extension plug.

In contrast, **IO-Link** is a newer, open communication standard developed by the IO-Link research group of the PROFIBUS & PROFINET International organization in response to the need for a simple, low-cost way to allow actuator and sensor communication in a more concentrated area, such for a control panel or individual machine.

IO-Link is a **point-to-point system**, not a field bus. It uses a three-wire cable, 24 VDC power supply, and an IO-Link master. Up to 16 devices per master are allowed, depending on the number of ports on the master. The maximum distance between the master and an actuator or sensor is 20 meters. An IO-Link master, such as the SIRIUS 4SI electronic module for SIMATIC ET 200S, allows IO-Link devices to be incorporated into a PLC control scheme with communication to higher level networks.

Siemens extensive array of IO-Link compatible devices, combined with the low cost and ease of application for IO-Link, makes more extensive actuator-sensor communication practical and drives down the life-cycle costs for machines and systems implemented using IO-Link.



Review 6

1. SIRIUS motor starter components are available in sizes S00, S0, S2, S3, S6, ________ and ________.

2. SIRIUS Innovations additions to the SIRIUS modular system include a complete redesign of _______ and ________ components.

3. SIRIUS 3RT2 contactor function modules are available with connections for ________ and ________ communication.

4. SIRIUS ________ incorporate a motor starter protector, contactor, electronic overload relay in one unit.

5. SIRIUS ________ is an enclosed motor starter with communication capability.

6. The SIRIUS modular system includes ________ and ________ soft starters for standard applications and ________ soft starters for high feature applications.

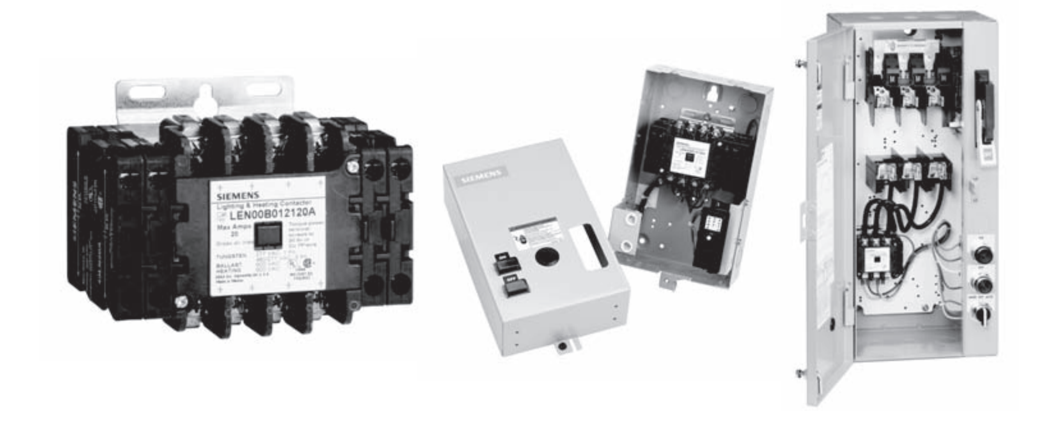
7. Field buses like ________ and _________ provide efficient communication enabling the use of distributed intelligence.

8. ________ is a point-to-point system that provides a simple, low-cost way to allow actuator and sensor communication for a machine or control panel.

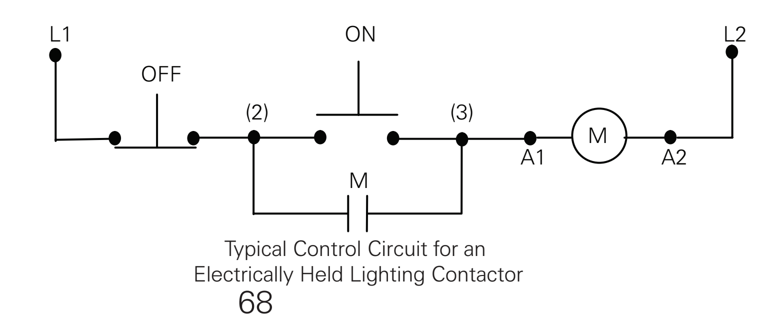
Electrically Held Contactors

Most commercial lighting and heating applications require the use of a contactor to control the loads. One type of contactor used in these applications is an **electrically held contactor**, which is similar to the contactor used with a magnetic motor starter. Unlike a starter contactor, however, the lighting and heating contactor is designed for lighting and resistive heating loads rather than motor loads.

Siemens **Class LE lighting and heating contactors** are available with 2 to 12 poles and current ratings from 20 to 400 amps. They can be used with 480 VAC tungsten and 600 VAC ballast-type lighting loads as well as 600 VAC resistive loads. Combination and non-combination enclosures are also available.



Electrically held lighting and heating contactors have the same operating principles as the magnetic contactors covered earlier in this course. Therefore, the control circuit for an electrically held lighting and heating contactor is similar to the start-stop circuit for a motor starter. Because the contacts of this type of contactor are electrically held, these contacts open when control power is lost.

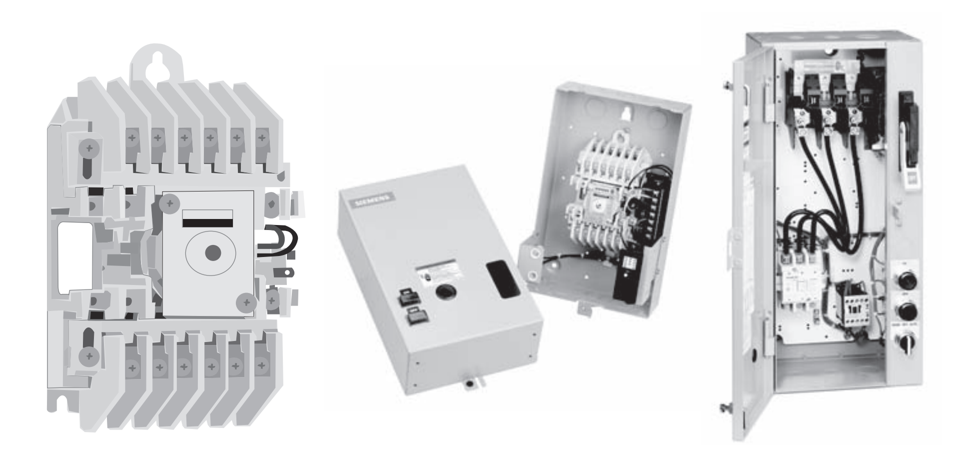


Typical Control Circuit for an Electrically Held Lighting Contactor

Electrically held contactors are typically used in applications where noise is not an issue. These contactors have an inherent hum when current is supplied to the coil to hold the contacts closed. As a result, this type of contactor is not recommended where the humming can be heard and will disturb building occupants such as in libraries, hospitals, and some commercial buildings.

Magnetically Held and Mechanically Latched Contactors

Magnetically held and mechanically latched contactors are also designed for lighting and resistive heating loads. Siemens Class CLM lighting and heating contactors are available with 2 to 12 poles and current ratings from 20 to 400 amps. They can be used on 480 VAC tungsten, 600 VAC ballast, and general type lighting and resistive heating loads.



A magnetically held contactor contains a permanent magnet. When the contactor is energized, current through a coil creates a magnetic field that reinforces the permanent magnet and closes the contacts. Current through the coil is then interrupted and the contacts are held closed by the permanent magnet even if control power is lost. Contacts are opened magnetically when an OFF coil is energized.

A mechanically latched contactor has contacts that are mechanically latched closed when the contactor is energized and remain latched until a trip solenoid receives a signal to release the mechanical latch.

Magnetically held and mechanically latched contactors are typically used where noise is a concern or where it is desired to maintain closed contacts when power is lost so that current will be immediately provided when power resumes.

Pilot Devices

A **pilot device** directs the operation of another device or indicates the status of an operating machine or system. Siemens pilot devices are available with a variety of features and mounting dimensions and include product selections appropriate for a broad range of applications. The following product families are available. The mounting diameter refers to the size of the knockout hole (in millimeters) required to mount the devices.

- **3SB2 devices** with 16 mm mounting diameters
- **3SB3 devices** with 22 mm mounting diameters
- **3SF5 stations** for the integration of 3SB3 devices in AS-Interface enclosures
- **Class 52 devices** with 30 mm mounting diameters are heavy duty products that are oil tight and designed for harsh, industrial environments
- **Class 52 heavy duty pushbutton enclosures** for use with Class 52 devices
- **Class 51 devices** for use where the presence of flammable gases, vapors, or finely pulverized dust create the threat of explosion or fire
- **Class 50 standard duty pushbutton stations** for use with magnetic controllers to start, stop, reverse, or adjust the speed of applicable motors

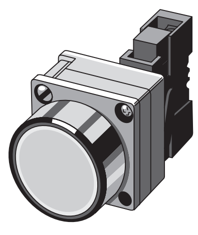
The following paragraphs provide basic application information for some of the types of devices listed above.

Pushbuttons

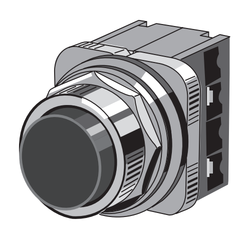
A **pushbutton** is a control device used to manually open and close a set of contacts. Pushbuttons may be illuminated or non-illuminated, and are available in a variety of configurations and actuator colors.



16 mm 3SB2 Pushbutton



22 mm SIGNUM 3SB3 Pushbutton

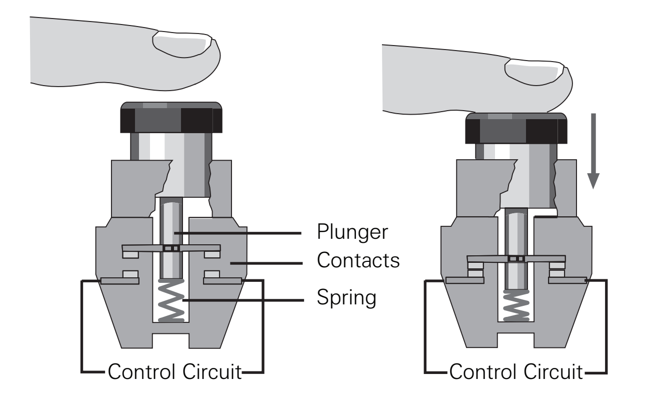


30 mm Class 52 Pushbutton

Normally Open Pushbuttons

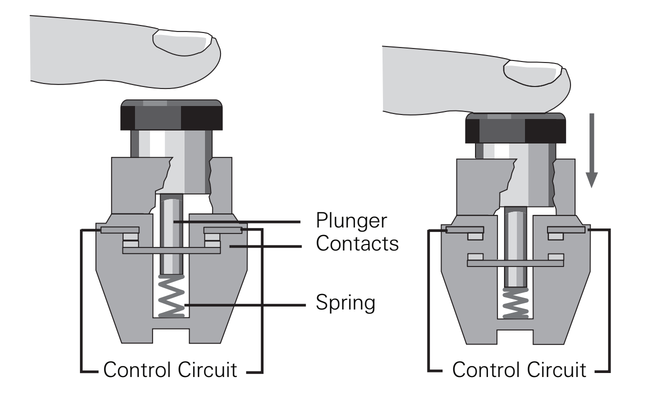
Pushbuttons are used in control circuits to perform various functions, for example, starting and stopping a motor. A typical pushbutton uses an operating plunger, a return spring, and one set of contacts.

The following drawing illustrates a normally open (NO) pushbutton, so called because the contacts are open unless the button is pressed. Pressing the button causes the contacts to close. When the button is released, the spring returns the plunger to the open position.



Normally Closed Pushbuttons

Normally closed (NC) pushbuttons, such as the one shown in the following illustration, are also used to open and close a circuit. In the normal position, the contacts are closed and current can flow through them. Pressing the button opens the contacts, preventing current flow through the circuit.

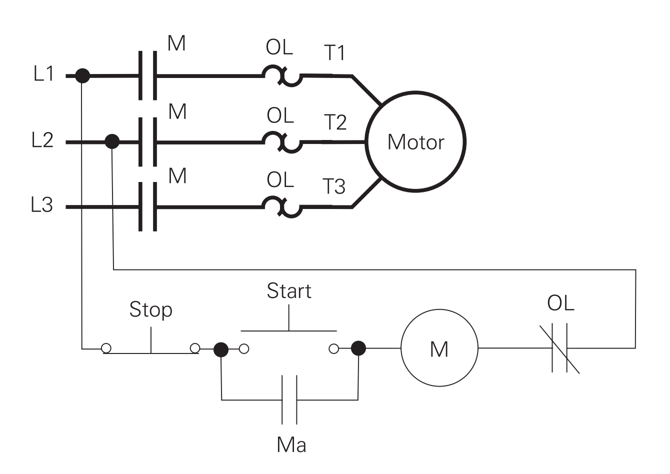


The pushbuttons just described are **momentary contact** pushbuttons because their contacts remain in their activated state only as long as the button is pressed. Pushbuttons with contacts that remain in their activated state after the button is released are called **maintained contact** pushbuttons.

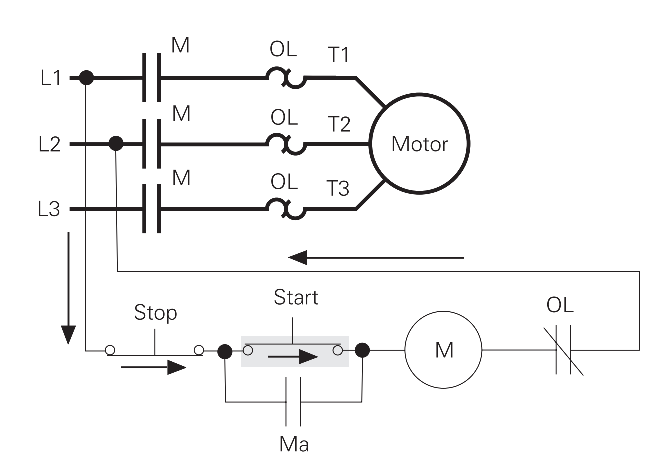
Pushbuttons are available with various contact configurations. For example, a pushbutton may have one set of normally open and one set of normally closed contacts so that, when the button is pressed, one set of contacts open and the other set is closes. In this example, the pushbutton can be wired to function as either a normally open or normally closed pushbutton.

Using Pushbuttons in a Control Circuit

The following line diagram shows an example of how a normally open and a normally closed pushbutton might be used in a control circuit.



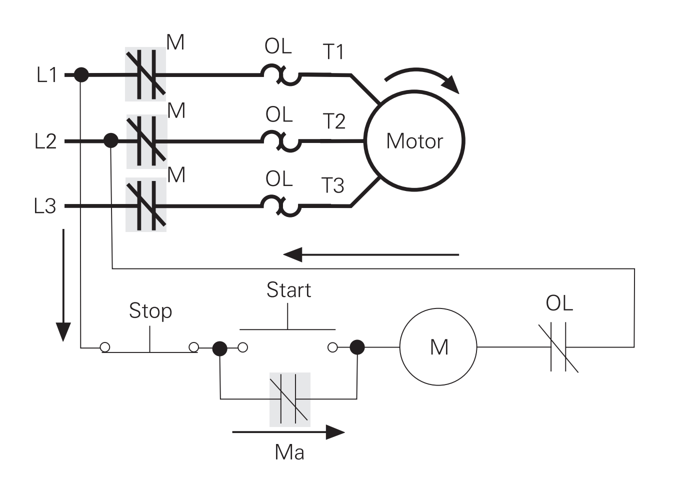
Momentarily pressing the Start pushbutton completes the path of current flow and energizes the M contactor's electromagnetic coil.



Three-Wire Control

Pressing the Start pushbutton closes the M and Ma contacts. When the Start pushbutton is released, auxiliary contacts Ma function as a **holding circuit** supplying power to the M electromagnetic coil. The motor will run until the normally closed Stop pushbutton is pressed, breaking the path of current flow to the M electromagnetic coil and opening the M and Ma contacts.

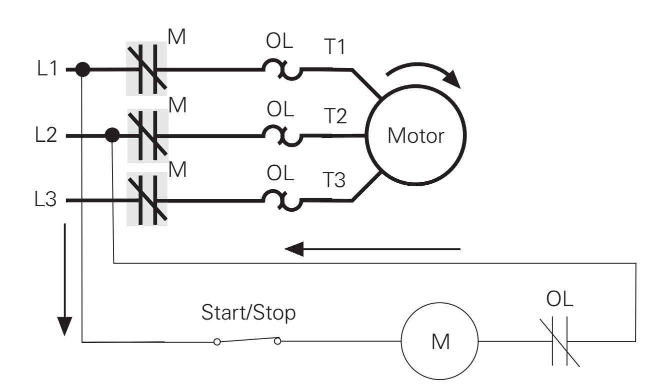
This is referred to as **three-wire control** because three wires are required to connect the Start and Stop pushbuttons and the holding circuit (Ma). An advantage of three-wire control that the motor will not automatically restart after an overload. When an overload causes the OL contacts in the control circuit to open, the M coil de-energizes and the motor shuts down. When the overload is cleared, an operator must depress the Start button to restart the motor.



This circuit also has **low voltage protection** because if control power is lost, it will shut down the motor and will not automatically restart the motor when control power is regained.

Two-Wire Control

Contrast this operation with that of a **two-wire control** circuit, so called because the Start/Stop switch requires only two wires to connect it into the circuit. This circuit provides **low-voltage release**, but not low-voltage protection. Low-voltage release means that in the event of a loss of control power, the contactor de-energizes, stopping the motor. However, when control power is restored, the motor will restart immediately if the control device is still closed.



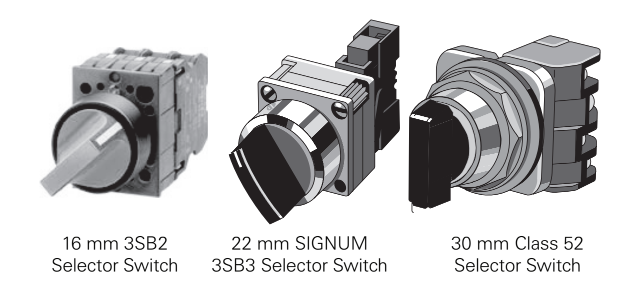
This type of control scheme is used for remote or inaccessible installations where it is often desirable to have an immediate return to service when power is restored.

Selector Switches

Selector switches are also used to manually open and close contacts. Selector switches can be **maintained**, **spring return**, or **key operated** and are available in two, three, and four-position types.

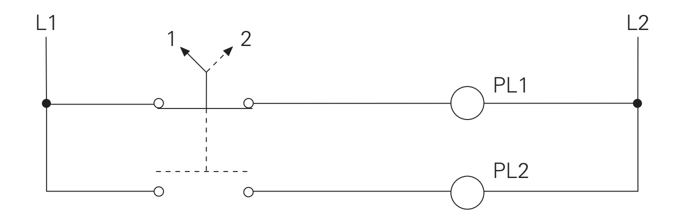
The basic difference between a pushbutton and a selector switch is the operator mechanism. With a selector switch, the operator is rotated to open and close contacts. Contact blocks used on pushbuttons are often interchangeable with those used on selector switches of the same type.

Selector switches are used to select one of two or more circuit possibilities, for example, stop and run or stop, low speed, and high speed.



Two-Position Selector Switch

In the following example, pilot light PL1 is on when the switch is in position 1, and pilot light PL2 is on when the switch is in position 2. This is only part of a control circuit for a machine and the status of the pilot lights could be used to indicate either of two machine conditions, for example, stop and run.

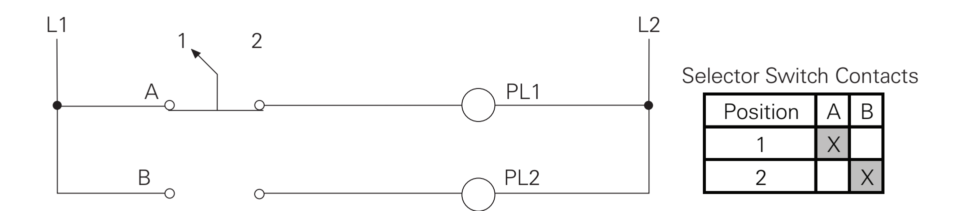


Contact Truth Tables

There are two accepted methods for indicating contact positions of a selector switch. The first method, shown in the previous example, uses solid and dashed lines to show contact positions.

The second method uses a **truth table,** also known as a **target table**, which uses a letter to represent each contact position. An X in the truth table indicates which contacts are closed for a given switch position.

In the example below, the switch is in position 1, contact A is closed and pilot light PL1 is on. When the switch is in position 2, contact B is closed and pilot light PL2 is on.

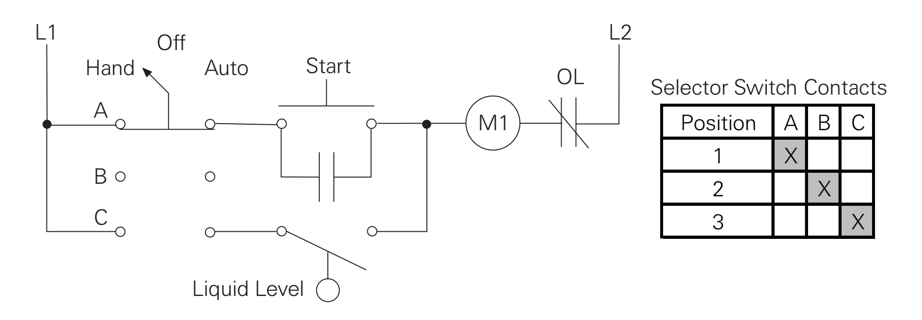


Position	A	B
1	X	
2		X

Three-Position Selector Switch

A three-position selector switch is used to select any of three contact positions. For example, the following diagram shows a Hand/Off/Auto control circuit for a pump motor.

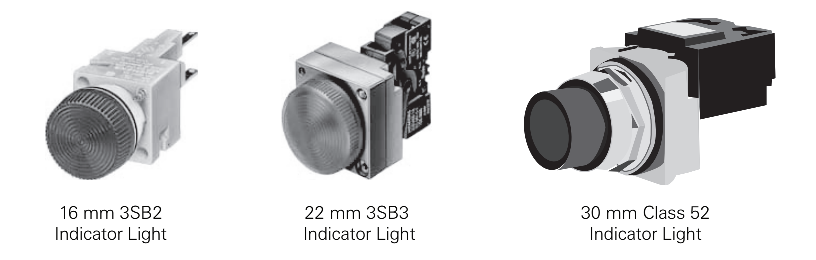
In the Hand (manual) position, the pump starts when the Start pushbutton is pressed. The pump is stopped by switching to the Off position. The liquid level switch has no effect until the selector switch is set to Auto. Then, the pump is controlled by the liquid-level switch. The liquid level switch closes when the fluid rises to a preset level, starting the pump. When the fluid drops to a lower preset level, the liquid level switch opens, stopping the pump.



Position	A	B	C
1	X		
2		X	
3			X

Indicator Lights

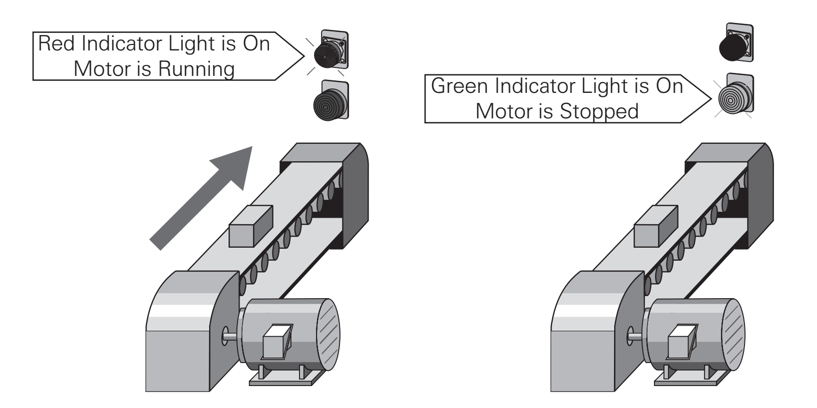
Indicator lights, also referred to as **pilot lights**, provide a visual indication of a circuit's operating condition, for example, on, off, or alarm.



16 mm 3SB2 Indicator Light   22 mm 3SB3 Indicator Light   30 mm Class 52 Indicator Light

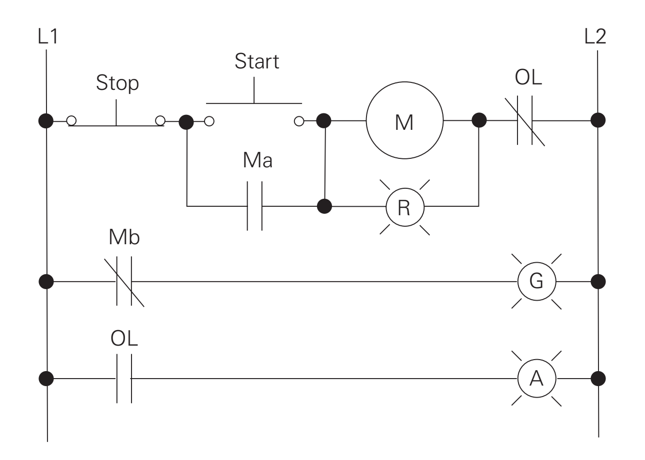
Indicator lights are available with a variety of lens colors to allow for a quick visual indication of machine or process status. Siemens indicator lights are available with a red, green, amber, blue, white, or clear lens.

As shown in the following illustration, a red indicator light often indicates that a system is running and a green indicator light often indicates that a system is off.

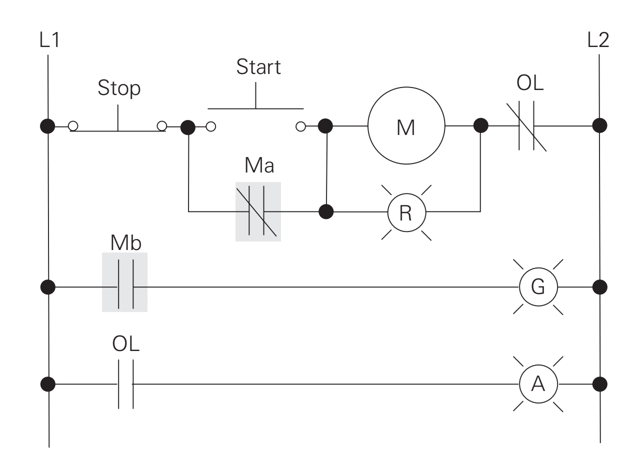


Using an Indicator Light in a Control Circuit

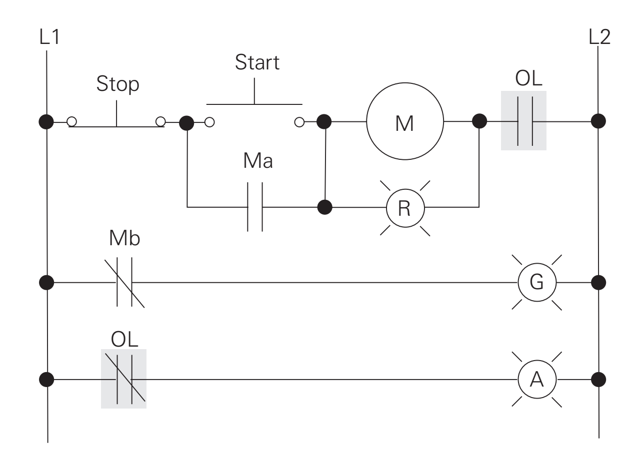
In the following diagram, when the motor is stopped, the normally closed Mb contact is closed, and the green (G) light is on.



When the coil is energized, the red (R) light is on to indicate that the motor is running. In addition, the Mb contact is now open, and the green light is off. Note that the indicator light is wired in parallel with the coil so that the motor will turn on even if the indicator light burns out.



If an overload occurs, the normally closed OL contact opens, stopping the motor and turning off the red light, the Mb contact closes, turning on the green light, and the normally open OL contact closes, turning on the amber (A) light.



Signaling Columns and Lamps

Signaling columns allow operating personnel to monitor machine or process operation from a distance. Columns are easily assembled by stacking elements to achieve the desired configuration. Various visual elements are available to provide steady, flashing, and rotating beacon indications in five colors: red, yellow, green, white, and blue. Buzzer or siren elements can be added to provide audible indications of machine or process conditions.

SIRIUS **8WD4 signaling columns** are available with either a 50 mm or 70 mm mounting diameter and can be networked to other devices through an optional AS-Interface adapter.

SIRIUS **8WD5 integrated signal lamps** have a 70 mm mounting diameter and can be directly attached to a machine. They are available with red, yellow, green, blue or clear lenses and with incandescent filaments or LEDs.



Review 7

1. ________ lighting and heating contactors are best used in applications where noise is not an issue.

2. Once their contacts are closed, ________ and ________ lighting and heating contactors keep their contacts closed even if control power is lost.

3. A ________ device directs the operation of another device or indicates the status of an operating system.

4. Siemens 3SB3 pushbuttons, selector switches, and indicator lights have a ________ mm mounting diameter.

5. Siemens indicator lights are available with the following lenses: red, green, amber, ________, ________, and ________.

6. SIRIUS 8WD4 signaling columns are available with either a ________ or ________ mounting diameter and can be networked to other devices through an optional ________ adapter.

7. SIRIUS 8WD5 ________ have a 70 mm mounting diameter and can be directly attached to a machine.

Limit Switches

Limit switches are part of an assortment of position switches used to mechanically detect the position of an object. Each limit switch has an operating head with a lever arm or plunger mechanism and a switch body that includes contacts.

When an object moves the lever arm or depresses the plunger, contacts in the limit switch change state (open to closed or vice versa). This contact state change is typically used to signal another device or system to respond.

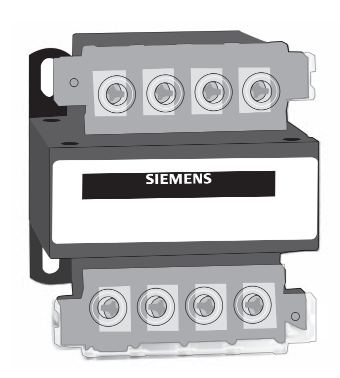
Siemens offers a variety of limit switches and accessories including **3SE03 North American limit switches**, designed to NEMA specifications, and **SIRIUS 3SE2, 3SE3, and 3SE5 limit switche**s, designed to IEC specifications. SIRIUS 3SE5 limit switches are part of the SIRIUS system of Safety Integrated products discussed later in this course.



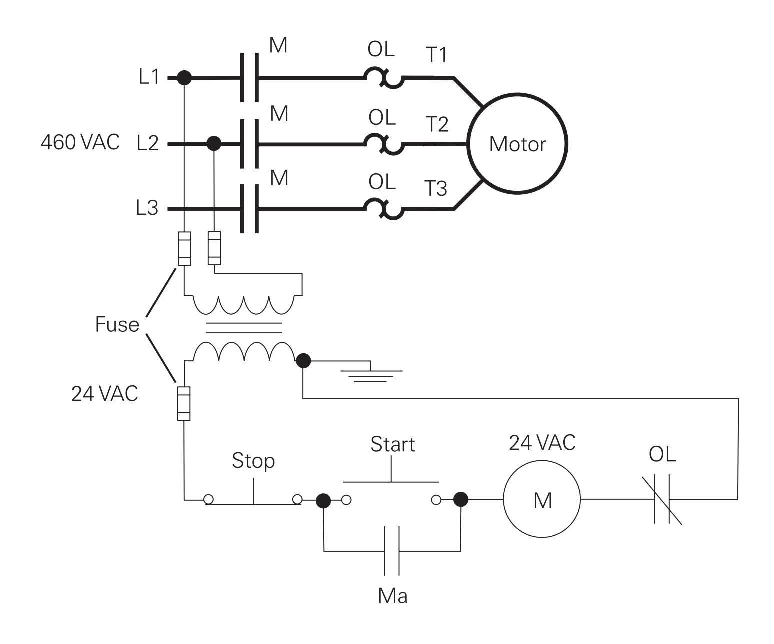
SIRIUS 3SE5 Limit Switches

Control Transformers

The voltage applied to the main terminals of an industrial motor is frequently higher than the voltage needed by a control circuit. In such cases, a **control power transformer (CPT)** is used to step down the voltage. Siemens **Class MT and Class MTG control power transformers** are available for a variety of primary and secondary voltages with apparent power ratings from 25 VA to 5 kVA.



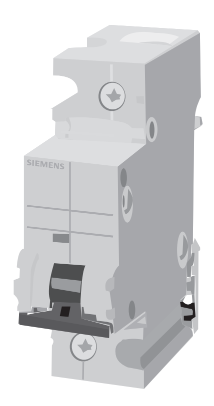
In the following example, the voltage on the primary of the CPT is 460 VAC. This voltage is stepped down to 24 VAC for use in the control circuit. Fuses connected to the CPT primary and secondary windings provide overcurrent protection for the transformer.



5SX, 5SY, and 5SP Supplementary Protectors

Siemens **UL 1077 supplementary protectors** are designed to trip faster than standard UL 489 circuit breakers providing additional protection for more sensitive devices. In addition to providing supplementary branch circuit protection, supplementary protectors may also be used as a local disconnect means inside a panel when a branch circuit protection device is already present.

Siemens supplementary protectors are equipped with a thermal bimetallic trip mechanism for low-current overloads and an instantaneous electromagnetic trip for high-current overloads and short circuits. Single-pole and multiple-pole varieties are available with mounting depths of 55 or 70 mm.



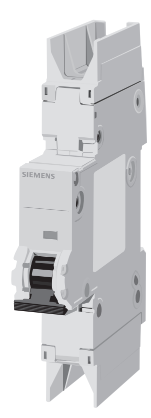
Supplementary Protector (70 mm)

5SJ4 Miniature Circuit Breakers

IEC style **miniature circuit breakers (MCBs)**, according to EN/IEC 60 898, are not always permitted in North America. For this reason, MCBs were developed that are based on the miniature circuit breakers of the 5SY series, but designed to meet the special requirements of **UL 489**.

For areas influenced by NEMA (National Electrical Manufacturers Association) and ANSI (American National Standards Institute), MCBs are certified as a solution for protective applications and can be used for branch circuit protection in the branches of control panels and systems.

MCB connection terminals are designed for the class: “Field wiring.” This means that, as well as being installed in a factory, these MCBs can be installed locally at customer sites. In addition to the permissible tripping ranges according to UL 489, device tripping characteristics C and D of EN/IEC 60 898 also apply. Therefore, these MCBs comply with both standards.



5SJ4 Miniature Circuit Breaker

Terminal Blocks

Siemens **terminal blocks** simplify the wiring of machines and system controls and incorporate screw, spring loaded, or insulation displacement connections that meet or exceed the requirements of CSA, IEC, NEMA, UL, VDE and other international standards. Meeting these requirements, combined with worldwide acceptability and availability, enables Siemens terminal blocks to be used domestically and incorporated into equipment intended for export.

Virtually all terminal block bodies are insulated on both sides, eliminating the need for barriers and end plates. The materials used are free of cadmium, halogens, or silicone. Except for bare terminals and solder connections, the terminals are finger-touch safe to IEC 60529 and EN 50274. Siemens terminal block lines include the following five connection types.

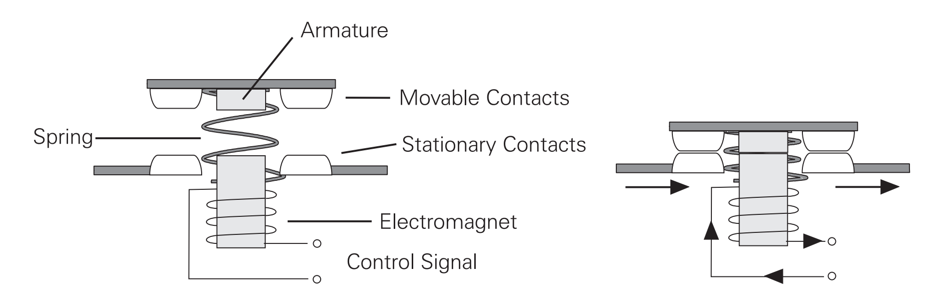
- 8WA1 terminals with screw connection
- 8WH2 terminals with spring loaded connection
- 8WH3 terminals with IDC connection
- 8WH4 terminals with push-in connection
- 8WH5 terminals with combi-plug connection

Control Relays

Control relays are widely used for switching multiple control circuits and to control light loads such as starting coils, indicator lights, and audible alarms.

Relay Operation

The operation of a control relay is similar to a contactor. In the following illustration, a relay with a set of normally open (NO) contacts is shown. When power is applied to the control circuit, the relay's coil (electromagnet) energizes, which then magnetically pulls the armature and movable contacts to the closed position. When power is removed the magnetic field is lost and spring tension pushes the armature and movable contacts to the open position.



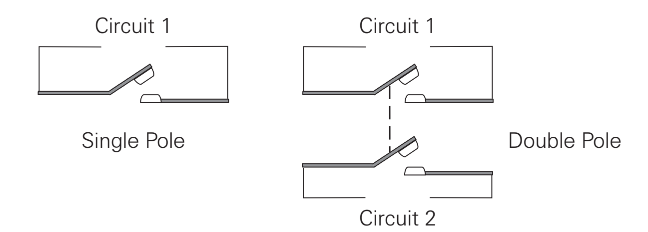
Contact Arrangement

A control relay usually has multiple normally open or normally closed contacts or both. The main difference between a control relay and a power relay or contactor is the size and number of contacts. The contacts in a control relay are relatively small because they need to handle only the small currents used in control circuits. The small size of control relay contacts allows a control relay to contain multiple isolated contacts.

The use of contacts in relays can be complex. There are three key terms that describe the operation of these contacts, pole, throw, and make.

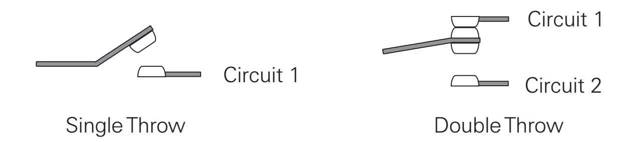
Pole

A control relay's **pole** number is the number of isolated circuits that can pass through the relay. This is the total number of circuits that can be controlled by the relay. Control relays often have multiple poles, but they need not all be used.



Throw

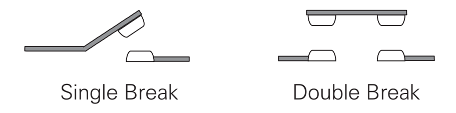
A control relay's **throw** number is the number of closed-contact positions per pole.



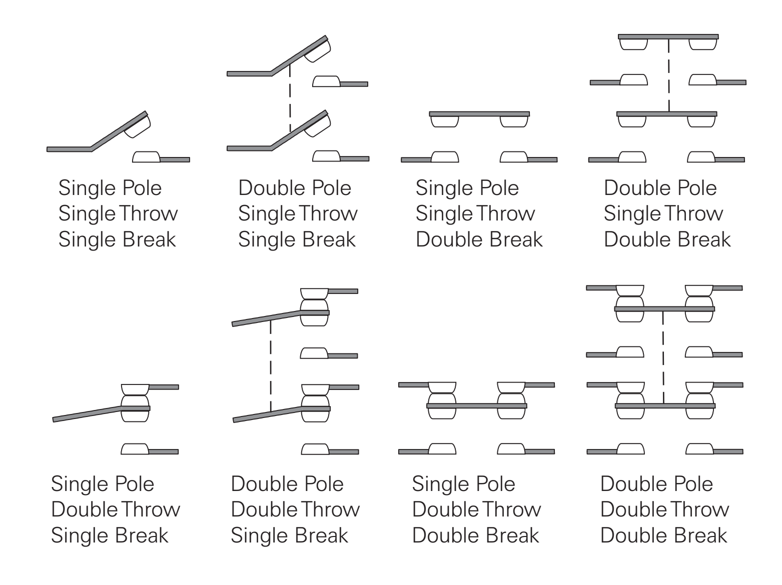
The following abbreviations are frequently used to indicate contact configurations: **SPST** (single pole, single throw), **SPDT** (single pole, double throw), **DPST** (double pole, single throw), and **DPDT** (double pole, double throw).

Break

A control relay contact **break** number is the number of separate contacts that open or close a circuit.

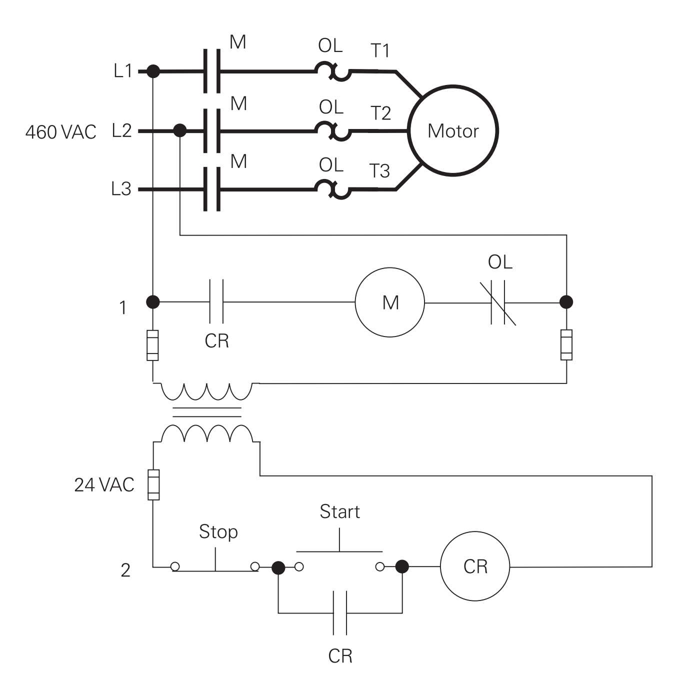


The following diagram illustrates various contact arrangements.

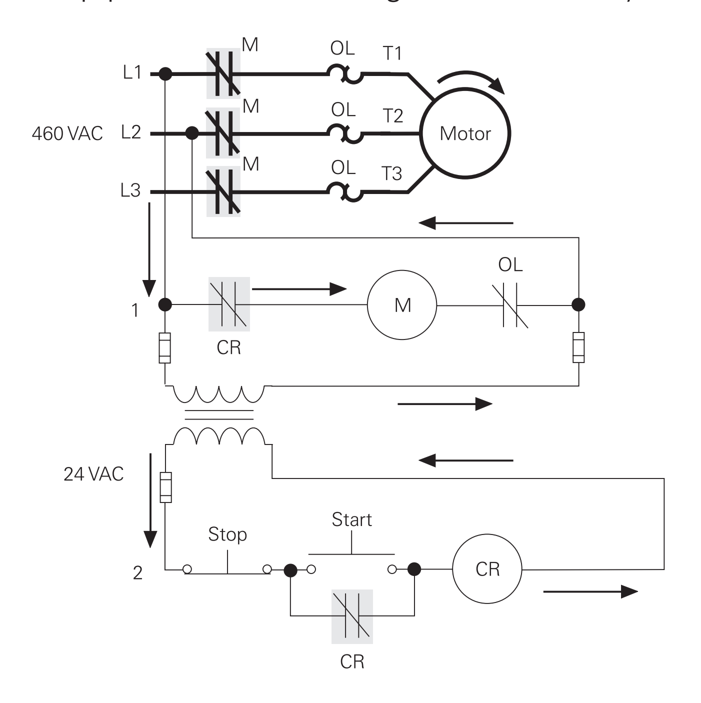


Interposing a Relay

The following line diagram illustrates one way that a control relay can be used in a 24 VAC control circuit. In this example, the 24 VAC coil is not strong enough to operate a large starter (M) that is rated for 460 VAC. This type of arrangement is called **interposing** a relay.



When the Start pushbutton is momentarily pressed, power is supplied to the control relay (CR), and the CR contacts in lines 1 and 2 close. The M motor starter energizes and closes the M contacts in the power circuit, starting the motor. Pressing the Stop pushbutton de-energizes the CR relay and M motor starter.



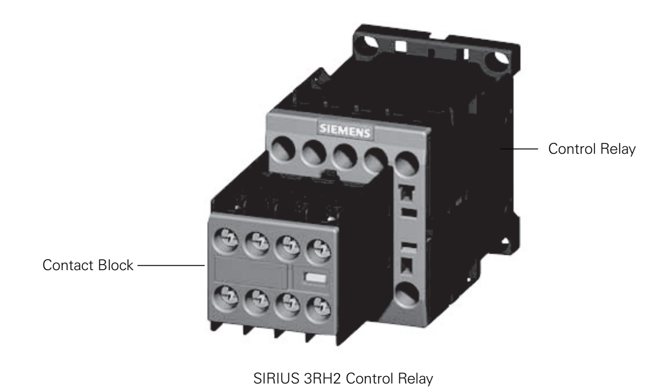
SIRIUS 3RH Control Relays

The SIRIUS modular system includes a complete line of control relays. For example, **SIRIUS 3RH control relays** and **latching control relays** are available with screw or spring-loaded terminals.

Four contacts are available in the basic device. A contact block with up to four additional contacts can be added to increase the number of contacts.

Units are available for control supply voltages from 12 to 230 VDC and from 24 to 600 VAC.

3RH latching control relays have two coils, a relay coil and a release coil, that are rated for continuous duty operation.



SIRIUS 3RH2 Control Relay

Solid-State Relays and Contactors

Conventional electromechanical switching devices are unsuitable for applications requiring high switching frequencies due to the wear on mechanical components. In addition, electromechanical switching devices are inherently noisy and, as a result, unsuitable for use in noise-sensitive areas.

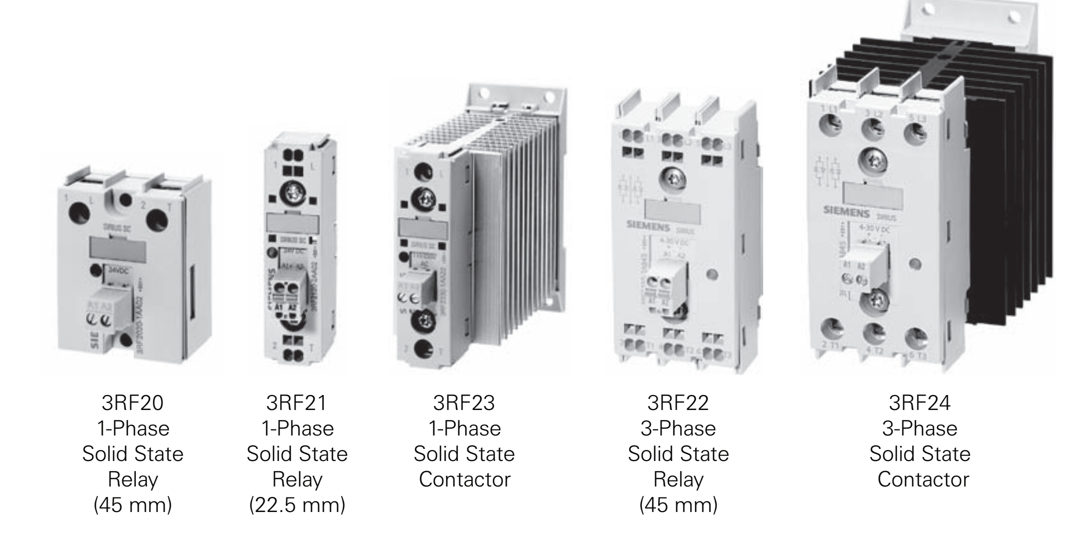
In addition to the SIRIUS 3RF2 contactors for motor loads discussed earlier in this course, Siemens also developed SIRIUS 3RF2 solid state relays and contactors for use with other types of loads. Versions are available for resistive loads, such as injection molding heater elements, or inductive loads, such as control valves. In addition to industrial applications, the quiet switching characteristics of these devices makes them suitable for use in commercial facilities.

SIRIUS Solid-State Relays

SIRIUS 3RF2 solid state relays can be mounted on existing cooling surfaces. **3RF21 single-phase, solid state relays** are 22.5 mm wide and **3RF20 single-phase** and **3RF22 three-phase, solid state relays** are 45 mm wide.

SIRIUS Solid-State Contactors

SIRIUS 3RF23 single-phase, solid state contactors and **3RF24 three-phase, solid state contactors** incorporate a solid state relay in an optimized heat sink to form a ready-to-use device with defined current ratings.



3RF20 1-Phase Solid State Relay (45 mm)	3RF21 1-Phase Solid State Relay (22.5 mm)	3RF23 1-Phase Solid State Contactor	3RF22 3-Phase Solid State Relay (45 mm)	3RF24 3-Phase Solid State Contactor

SIRIUS 3RF29 Function Modules

Many solid state switching applications require extended functionality that can be accommodated by using the following **SIRIUS 3RF29 function modules** together with SIRIUS 3RF2 relays or contactors.

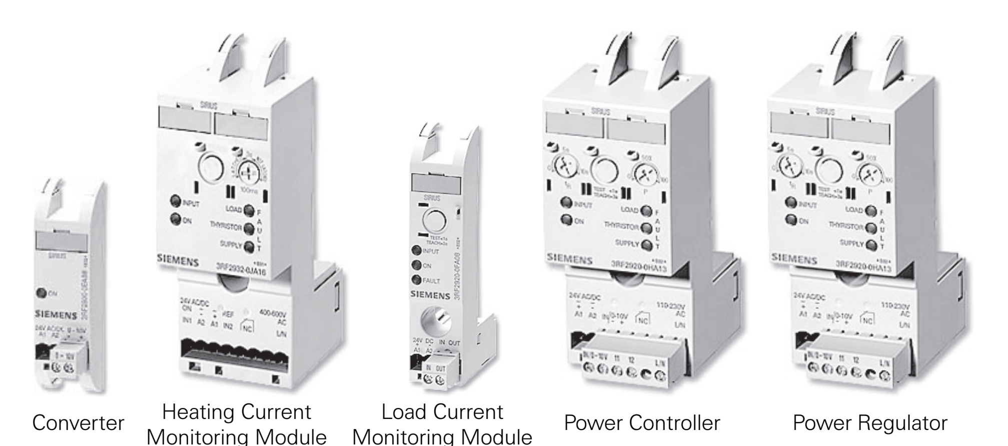
Converter – The module is used with single-phase and three-phase 3RF2 relays and contactors. This module converts an analog control signal to a pulse-width modulated digital signal. This allows a SIRIUS 3RF2 solid state relay or contactor to adjust power to a load based on an analog signal from a device such as a temperature controller.

Heating current monitoring module – This module is for use with single-phase 3RF2 relays and contactors used in heating applications. This module detects a variety of faults, including failure of load elements, and provides a fault indication by LEDs and a normally-closed relay contact.

Load monitoring module – This module is for use with single-phase 3RF2 relays and contactors. This module detects a variety of faults, including failure of load elements, and provides an LED fault indication and a PLC-compatible fault signal.

Power controller – This module is for use with single-phase 3RF2 relays and contactors for power control of complex heating systems and for operating inductive loads. This module combines load circuit monitoring capability and inrush current limitation with proportional control of the power to the connected loads.

Power regulator – This module is for use with single-phase 3RF2 relays and contactors for power control of complex heating systems and inductive loads. It combines load circuit monitoring and inrush current limitation with the ability to adjust power to the connected loads.

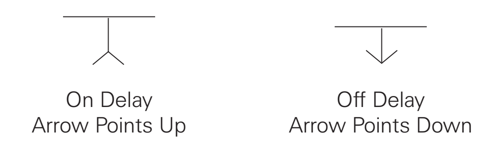


Converter | Heating Current Monitoring Module | Load Current Monitoring Module | Power Controller | Power Regulator

A **timing relay** is a device that does either on-delay timing or off-delay timing to delay some control response by a predetermined time.

Time Delay

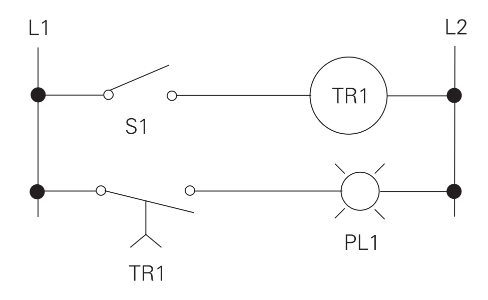
Time delay contacts have an arrow pointing up to indicates an **on-delay timing** action or an arrow pointing down to indicate an **off-delay timing** action.



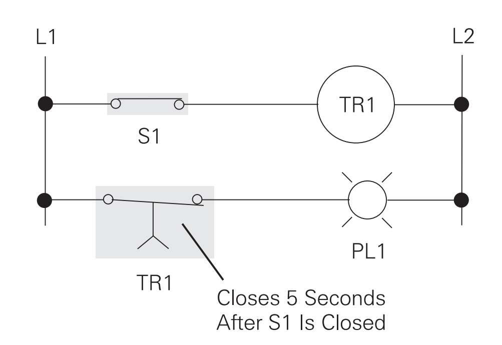
On-delay and off-delay timers can turn their connected loads on or off, depending on how the timer's output is wired into the circuit. The term "on delay" indicates that a preset time must pass after the timer receives a signal to turn on before the timer's contacts change state. The term "off delay" indicates that a preset time must pass after the timer receives a signal to turn off before the timer's contacts change state.

On-Delay, Timed Closed Timer

The following illustration shows an example of an **on-delay, timed closed timer**, also called a **normally open, timed closed (NOTC) timer**. In this example, The timing relay (TR1) has been set for an on delay of 5 seconds.

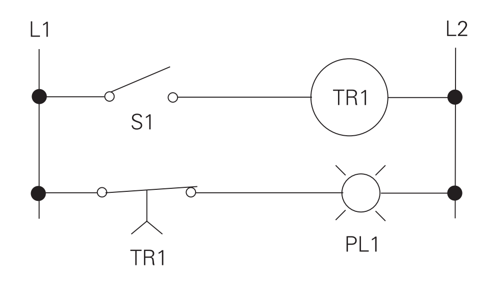


When S1 closes, timer TR1 begins timing. After 5 seconds, TR1 contacts close, and pilot light PL1 turns on. When S1 opens, timer TR1 de-energizes, and TR1 contacts open immediately, turning off pilot light PL1.

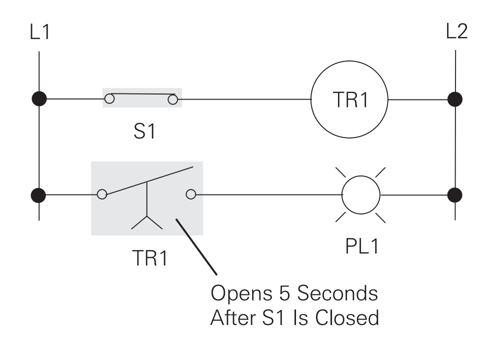


On-Delay, Timed Open Timer

The following illustration shows an example of an **on-delay, timed open timer**, also called a **normally closed, timed open (NCTO) timer**. The timing relay (TR1) has been set for an on delay of 5 seconds.



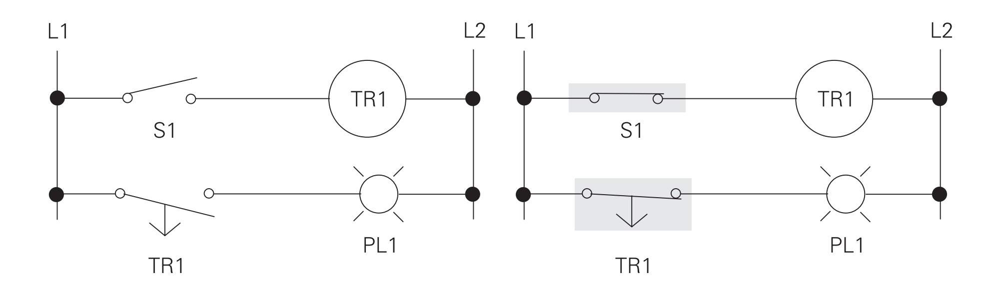
When S1 closes, timer TR1 energizes. After 5 seconds, TR1 contacts open, and pilot light PL1 turns off. When S1 opens, timer TR1 de-energizes, and TR1, contacts close immediately, turning on pilot light PL1.



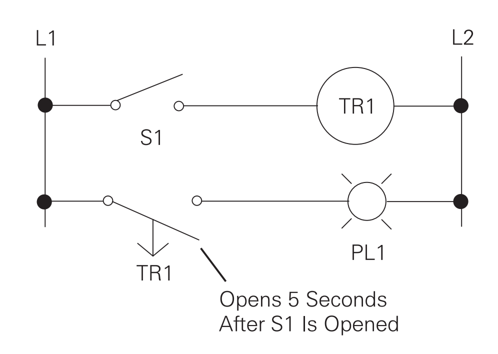
Off-Delay, Timed Open

The following illustrations show an example of an **off-delay, timed open timer**, also called a **normally open, timed open (NOTO) timer**. The timing relay (TR1) has been set for an off delay of 5 seconds.

When S1 closes, TR1 contacts close immediately, and pilot light PL1 turns on.

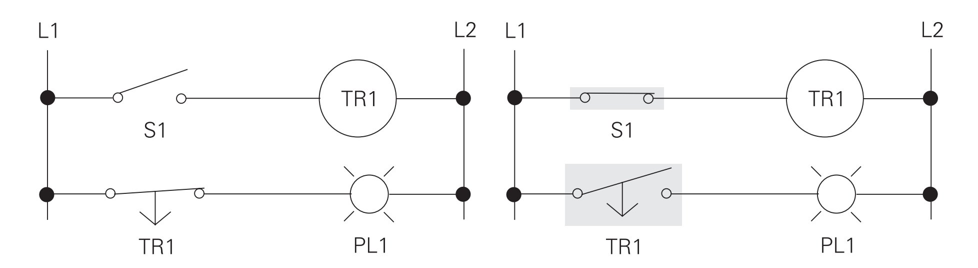


When S1 opens, timer TR1 begins timing. After 5 seconds, TR1 TR1 contacts open, and pilot light PL1 turns off.

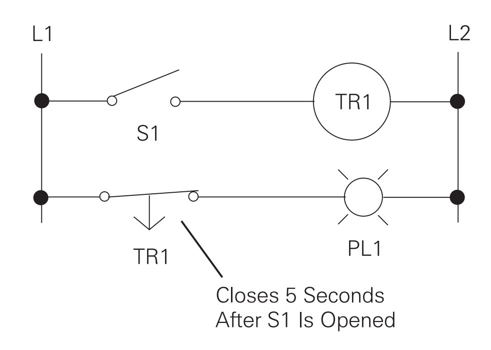


Off-Delay, Timed Closed

The following illustration shows an example of an **off-delay, timed closed timer**, also called a **normally closed, timed closed (NCTC) timer**. The timing relay (TR1) has been set for 5 seconds. When S1 closes, TR1 contacts open immediately, and pilot light PL1 turns off.

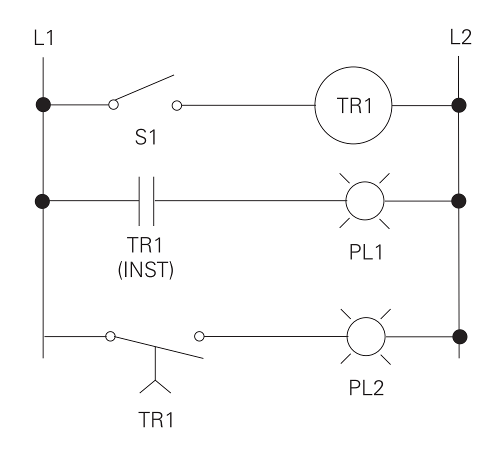


When S1 opens, timer TR1 begins timing. After 5 seconds, timer TR1 contacts close, and pilot light PL1 turns on.



Instantaneous Contacts

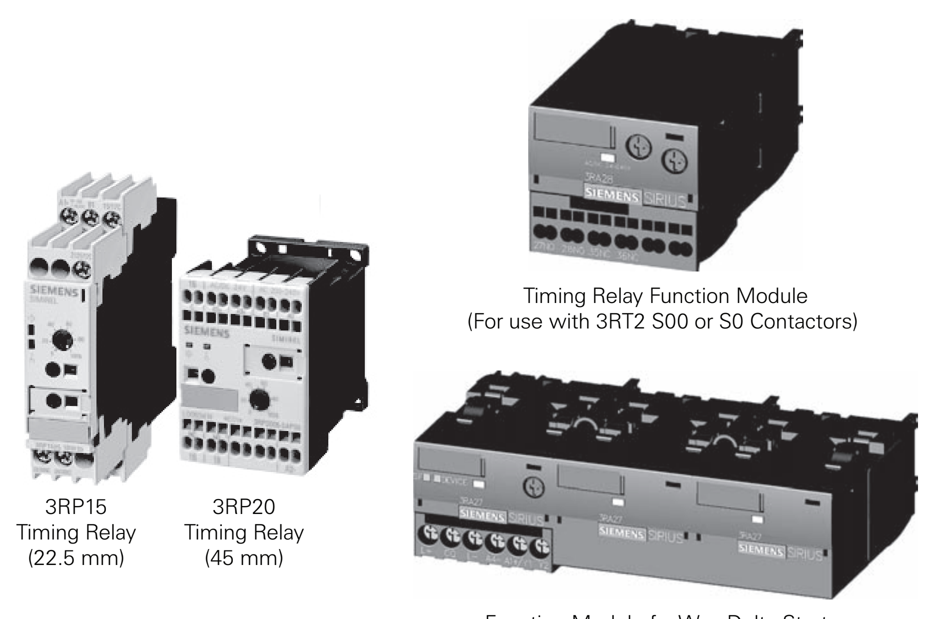
Timing relays can also have normally open or normally closed **instantaneous contacts**. In the following example, when switch S1 closes, TR1 instantaneous contacts close immediately, and pilot light PL1 turns on. After a preset time delay, TR1 timing contacts close, and pilot light PL2 turns on.



The SIRIUS modular system includes timing relays as well as timing relay function modules for use with SIRIUS contactors.

SIRIUS 3RP electronic timing relays have a compact design that makes them well suited for use in industrial control cabinets. They are optionally available with removable screw-type or spring-loaded terminals.

SIRIUS function modules can be easily plugged onto SIRIUS 3RT contactors. Single-contactor function modules make it easy to implement on-delay or off-delay timing. Wye-delta function modules include all the necessary timing and interlocking capabilities for wye-delta starters.



Timing Relay Function Module
(For use with 3RT2 S00 or S0 Contactors)

3RP15
Timing Relay
(22.5 mm)

3RP20
Timing Relay
(45 mm)

Function Module for Wye-Delta Starter
(for use with 3RT2 S00 or S0 contactors)

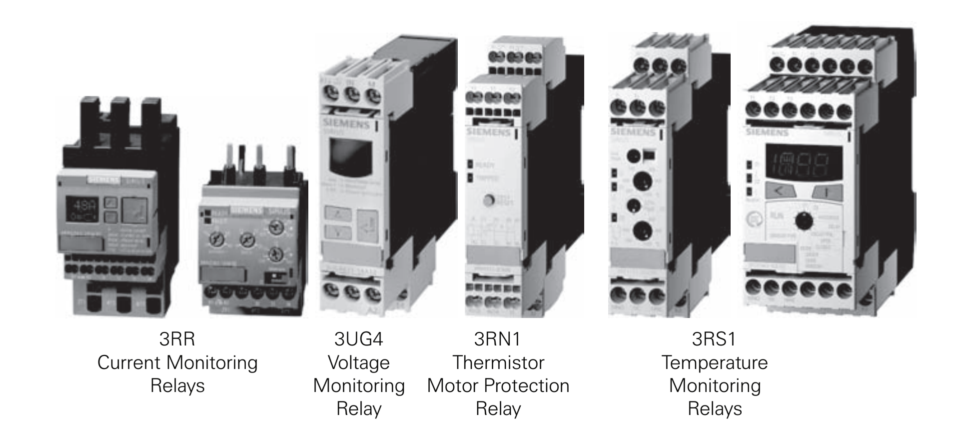
Monitoring Relays

Monitoring relays reduce machine and plant downtime by monitoring electrical and mechanical quantities and fault conditions and providing appropriate diagnostic indications.

The SIRIUS modular system includes a variety of monitoring relays in addition to the 3RR current monitoring relays discussed earlier in this course. Examples of additional functions performed by various monitoring relays include:

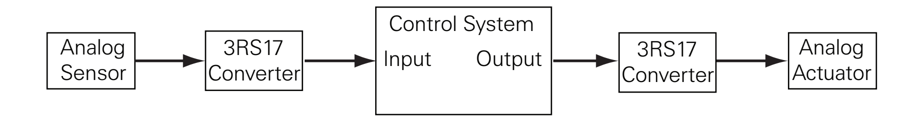
- Filling level monitoring
- Insulation resistance monitoring
- Line monitoring for phase sequence, phase failure, phase asymmetry, undervoltage, and overvoltage
- Motor speed monitoring
- Power factor monitoring
- Residual current (ground fault) monitoring
- Single-phase current monitoring
- Single-phase voltage monitoring
- Temperature monitoring
- Thermistor motor protection

The following illustration shows a few of the various types of monitoring relays available.

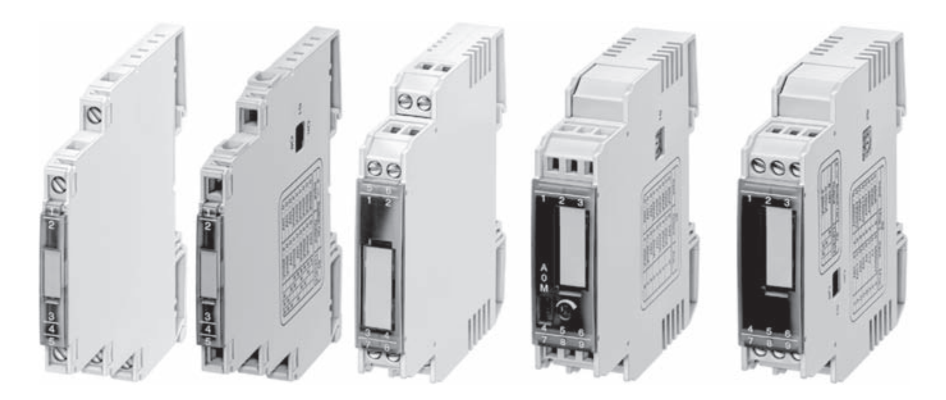


Interface Converters

Analog sensors and actuators may have different voltage or current ranges than the control system inputs or outputs they interface with. In addition, it is often necessary for signals to travel long distances through electrically noisy industrial environments. As a result, interface converters are frequently needed to electrically isolate and convert analog signals. These converters can also provide short circuit protection for a control system output.



SIRIUS 3RS17 interface converters are available in both active and passive types and for single or multiple signal lines. Active converters support complete voltage isolation as well as conversion of one signal type to another. Passive converters do not require an electrical supply voltage and are used with analog currents that do not require conversion.

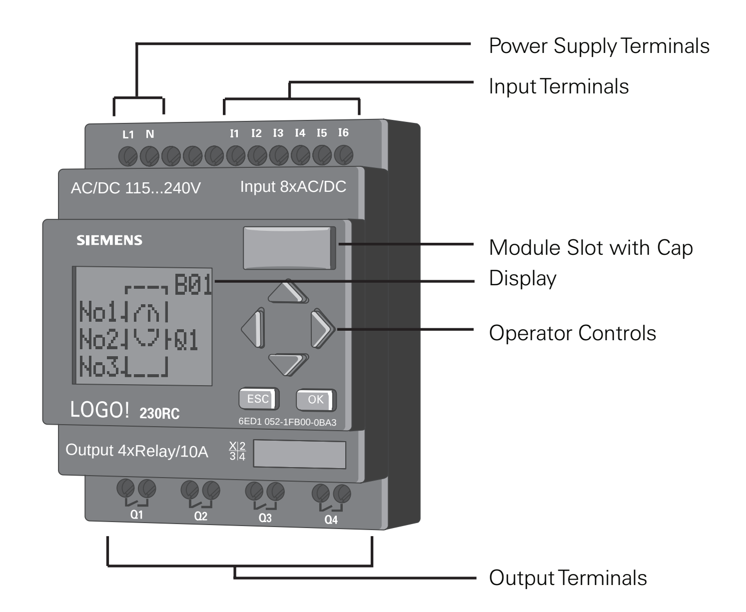


SIRIUS 3RS17 Interface Converters

LOGO! Programmable Relays

Siemens **LOGO!** is a **modular programmable relay system** used to perform basic control tasks that are otherwise often handled using hard-wired control relays and other devices.

A LOGO! system can be assembled using a **LOGO! Basic module** (shown below) with a built-in text display or a **LOGO! Pure module** without a built-in display. Either module offers an instruction set that includes eight basic functions and 31 special functions. **LOGO! Soft Comfort software** simplifies development of logic which can include ladder logic and function blocks.



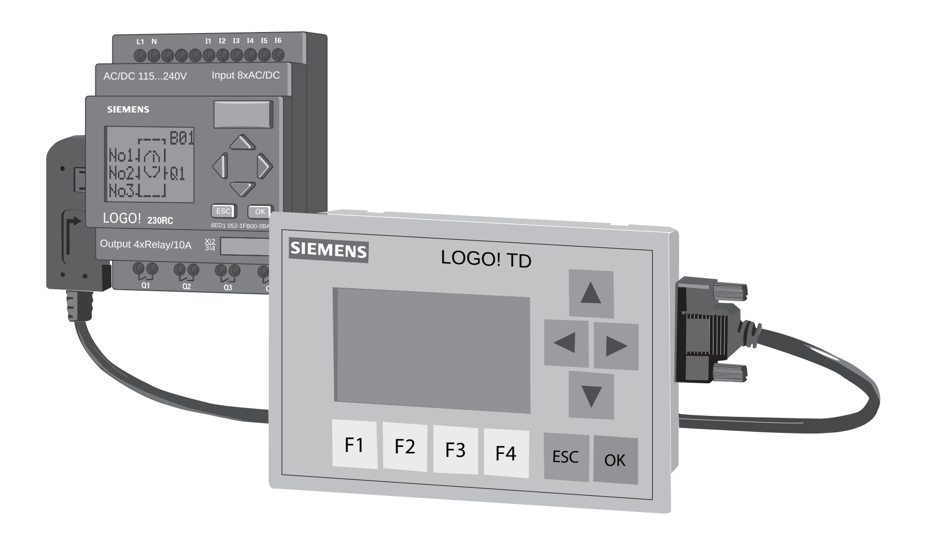
LOGO! Basic and **LOGO! Pure** versions are available for use with the following supply and input voltages: 12/24 VDC, 24 VDC, 24 VAC/DC, or 115/240 VAC/DC. All units can accept eight discrete inputs. For 12/24 VDC or 24 VDC units, four of these inputs are usable as 0 to 10 VDC analog inputs. All units also have four relay-type outputs except the 24 VDC units which have four solid-state discrete outputs.

As shown in the following chart, a variety of **expansion modules** are available to increase the number and types of inputs and outputs. Including the inputs and outputs on the controller module, LOGO! supports a maximum of 24 digital inputs, 8 analog inputs, 16 digital outputs, and 2 analog outputs.

Expansion Module	Power Supply	Inputs	Outputs
LOGO! DM 8 12/24R	12/24 VDC	4 discrete	4 relays (5A)
LOGO! DM 8 24	24 VDC	4 discrete	4 solid-state (24V/0.3A)
LOGO! DM 8 24R	24 VAC/DC	4 discrete	4 relays (5A)
LOGO! DM 8 230R	115-240 VAC/DC	4 discrete	4 relays (5A)
LOGO! DM 16 24	24 VDC	8 discrete	8 solid-state (24V/0.3A)
LOGO! DM 16 24R	24 VDC	8 discrete	8 relays (5A)
LOGO! DM 16 230R	115-240 VAC/DC	8 discrete	8 relays (5A)
LOGO! AM 2	12/24 VDC	2 analog 0-10 V or 0-20 mA	none
LOGO! AM 2 PT100	12/24 VDC	2 PT100 -50°C to +200°C	none
LOGO! AM 2 RTD	12/24 VDC	2 PT100 or 2PT1000 or 1 each -50°C to +200°C	none
LOGO! AM 2 AQ	24 VDC	none	2 analog 0-10 V or 0/4-20 mA

Two communication modules are available. One module is for connection to the AS-Interface, and the other module is for a KNX/EIB connection.

LOGO! TD is a backlit, four-line LCD supporting text or numeric displays up to 24 characters per line. The unit also supports a built-in horizontal and vertical bar graph display feature that can be configured to represent any numeric value in the LOGO! controller. LOGO! TD screens are developed using the LOGO! Soft Comfort software.



SIRIUS Safety Integrated

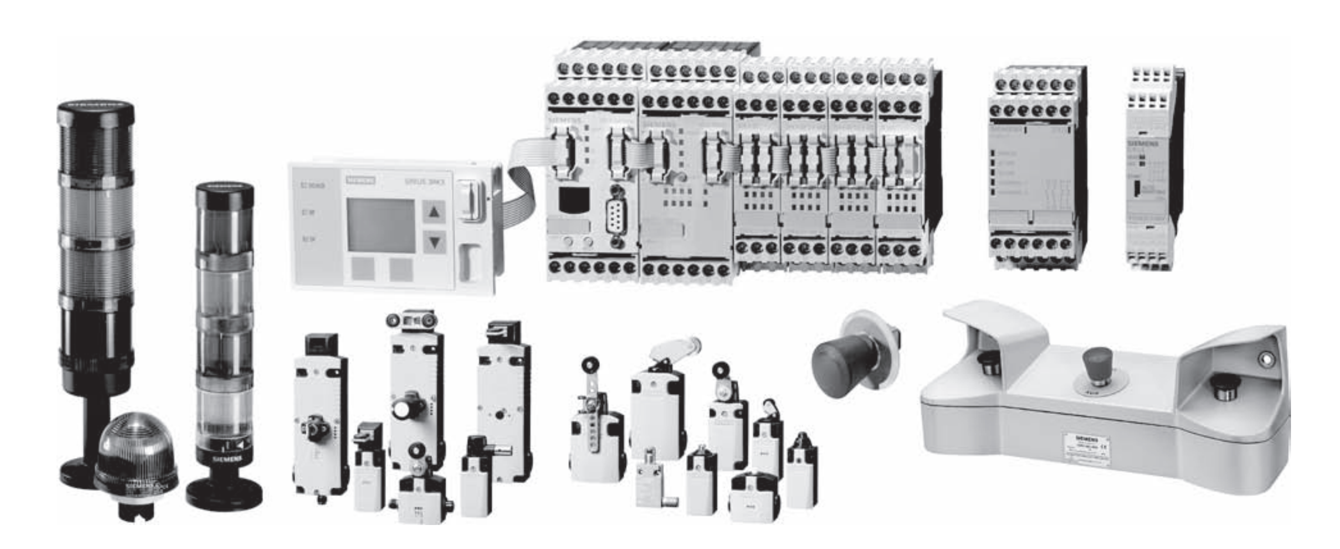
In recent years, safety has taken on an even greater importance both as a result of changing regulations and standards and the emergence of new technologies. As a result, Siemens developed the Safety Integrated system which includes products which offer comprehensive and consistent safety solutions for factory automation and process automation.

Because Safety Integrated has been developed consistent with Siemens Totally Integrated Automation (TIA) strategy, both standard and safety-related components are combined in one uniform system. This results in considerable cost savings for our customers.

SIRIUS Safety Integrated products are part of the Siemens Safety Integrated system of devices or systems associated with safety-oriented industrial applications.

While it is beyond the scope of this course to cover the full range of Siemens Safety Integrated products, the following pages provide examples of SIRIUS Safety Integrated products in the following categories:

- Detecting devices
- Commanding and signaling devices
- Monitoring and controlling devices and systems



Detecting Devices

SIRIUS detecting devices perform precise detection of position for machines and equipment in almost any application.

Included in this category of SIRIUS safety devices are **3SE2, 3SE3, 3SE5, 3SF1, and 3SF3 position switches** and **3SE6 magnetically operated switches**.

SIRIUS 3SE2, 3SE3, 3SE5, 3SF1, and 3SF3 position switches include:

- Limit switches for mechanical detection of position, as described earlier in this course
- Position switches with a separate actuator for use where the switching element is attached to a door frame and the actuator is attached to the door
- Position switches with tumbler for use when a locking mechanism is required for a protective door
- Hinge switches for detecting the position of a protective door or flap.
- 3SF1 and 3SF3 versions of the devices listed above with an integrated AS-Interface connection.

SIRIUS 3SE6 magnetically-operated switches operate without contact and are used to monitor protective doors. The reed contacts in the switching element are actuated by means of a coded switching magnet and are therefore tamper-proof.



3SE5 Position Switches

3SE6 Magnetically-Operated Switches

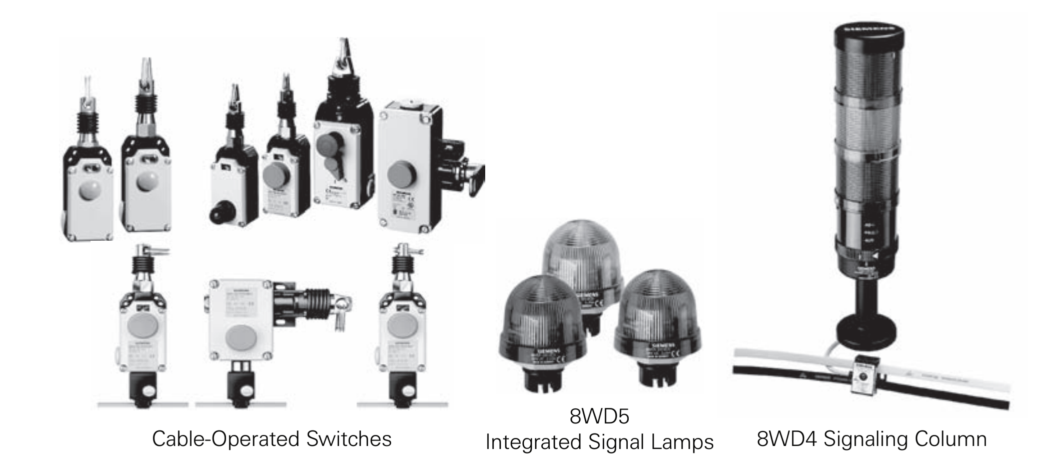
Commanding and Signaling Devices

SIRIUS commanding and signaling devices perform essential human-machine interaction tasks critical to the safe operation of equipment.

The following device types are included in this category:

- **SIRIUS 3SB2, 3SB3, and 3SB5 pushbuttons and indicator lights**
- **SIRIUS 3SB3 two-hand operation consoles**
- **SIRIUS 3SE7 and 3SF2 cable-operated switches**
- **SIRIUS 3SE2 and 3SE3 foot switches**
- **SIRIUS 8WD4 signaling columns**
- **SIRIUS 8WD5 integrated signal lamps**

Device types beginning with 3SF and selected other devices have an integrated AS-Interface connection.



Cable-Operated Switches

8WD5
Integrated Signal Lamps

8WD4 Signaling Column



3SB3 Pushbutton and Indicator Lights



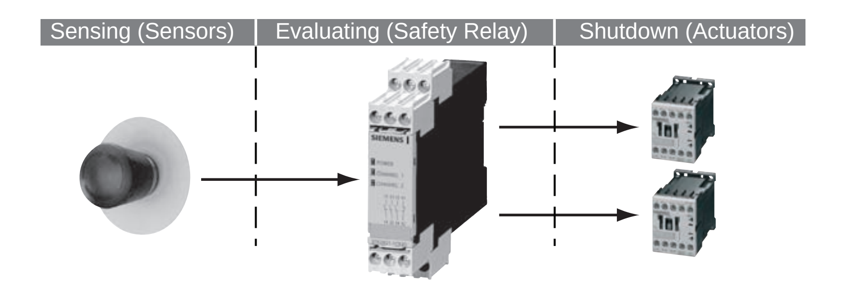
3SE2 Foot Switch



3SB3 Two-Hand Operation Console

Monitoring with Safety Relays

SIRIUS 3TK28 safety relays carry out the following safety tasks: emergency-stop (E-stop) switch off, protective door monitoring, and motor standstill and speed monitoring. They are available in the types described in the following paragraphs.



SIRIUS safety relays with relay enable circuits featuring positively-driven NO and NC contacts in pairs. If one of the contacts welds, then the other contact is used to shut down the circuit. A positively-driven feedback signal contact (NC contact) detects the fault of the defective NO contact.

SIRIUS safety relays with electronic enabling circuits have a compact design and can operate at considerably higher switching frequencies and with longer service life than similar devices with electromechanical contacts.

SIRIUS safety relay with contactor relay enable circuits combine electronic safety functionality with two redundant SIRIUS contactor relays assembled, wired, tested, and certified as a unit.

SIRIUS safe standstill monitor detects when a motor has stopped after shutdown and then permits access to restricted areas.

SIRIUS reliable speed monitor functions as both a motor continuous standstill monitor and a motor speed monitor.

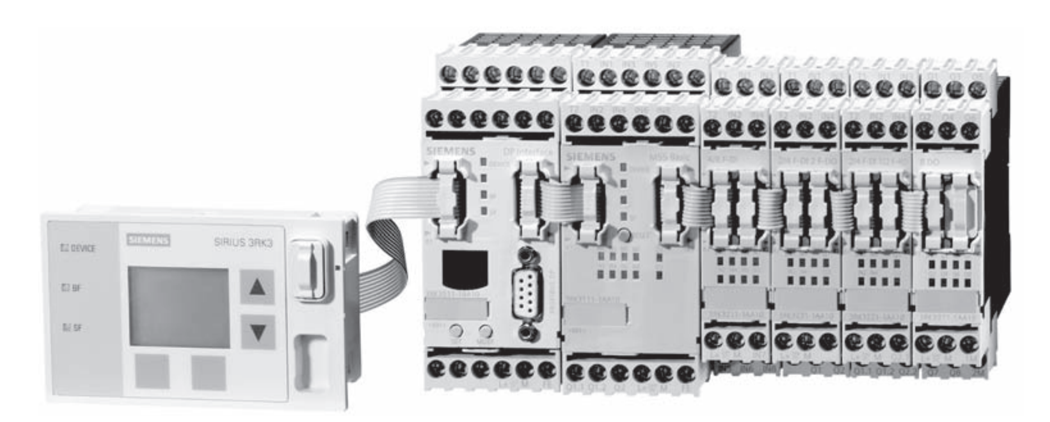


SIRIUS 3TK28 Safety Relays

Modular Safety System

SIRIUS 3RK3 modular safety system (MSS) combines the functionality of safety relays with a fail-safe programmable logic controller (PLC).

The 3RK MSS has a modular design that includes a central unit with eight safety-related inputs, one safety-related relay output, and one safety-related solid state output.



The input-output capability can be increased by adding up to seven expansion modules of various types. Four module types are available: eight safety-related inputs, four safety-related inputs and two relay outputs, four safety-related inputs and two solid state outputs, and eight standard outputs.

The DP interface module enables communication with higher-level controllers via PROFIBUS DP.

The SIRIUS 3RK36 diagnostics display option can be added to facilitate fast detection of the cause of system standstill in the event of a fault or when a safety sensor is tripped.

Modular Safety System ES (MSS ES) parameterization software simplifies system setup and commissioning tasks.

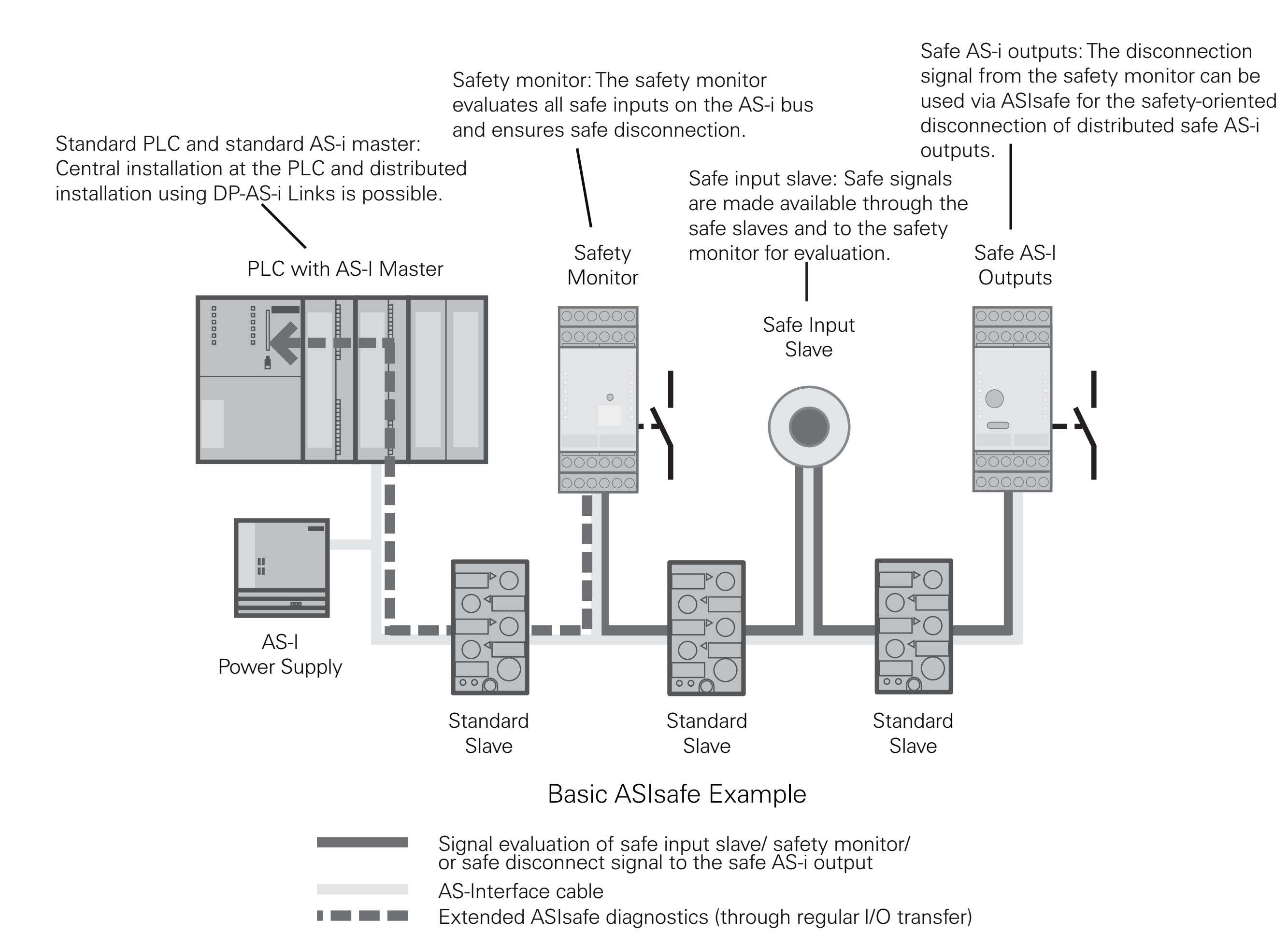
ASIsafe Communication

As previously discussed, the Actuator-Sensor Interface is a simple and effective networking system for the field level. It is extremely rugged, even under the toughest of conditions. The safety-related design of AS-Interface was standardized for all manufacturers in the Safety at Work consortium (a sub-group of the AS-i International Association). It is marketed by Siemens under the copyrighted name **ASIsafe**.

ASIsafe allows both standard and safe data to be used in one bus system. Emergency STOP pushbuttons and a variety of other field devices can be easily and safely connected directly to the yellow AS-Interface cable . These devices are fully compatible with standard AS-Interface components.

The signals from safety sensors are evaluated by a safety monitor, which not only monitors the switching signals from the safety sensors, but also continuously ensures that data is transferred properly. The safety monitor is equipped with one or two enabling circuits, which are configured with one or two channels and are used to switch the machine or plant to safe mode. Sensors and monitors can be connected anywhere within the AS-Interface network. More than one monitor can also be used in a network.

The ASIsafe system is can be used to meet a range of communication requirements from a small, local ASIsafe solution and to a plant-wide ASIsafe network using the DP/AS-i F link as the transition from ASIsafe to a PROFIsafe network.

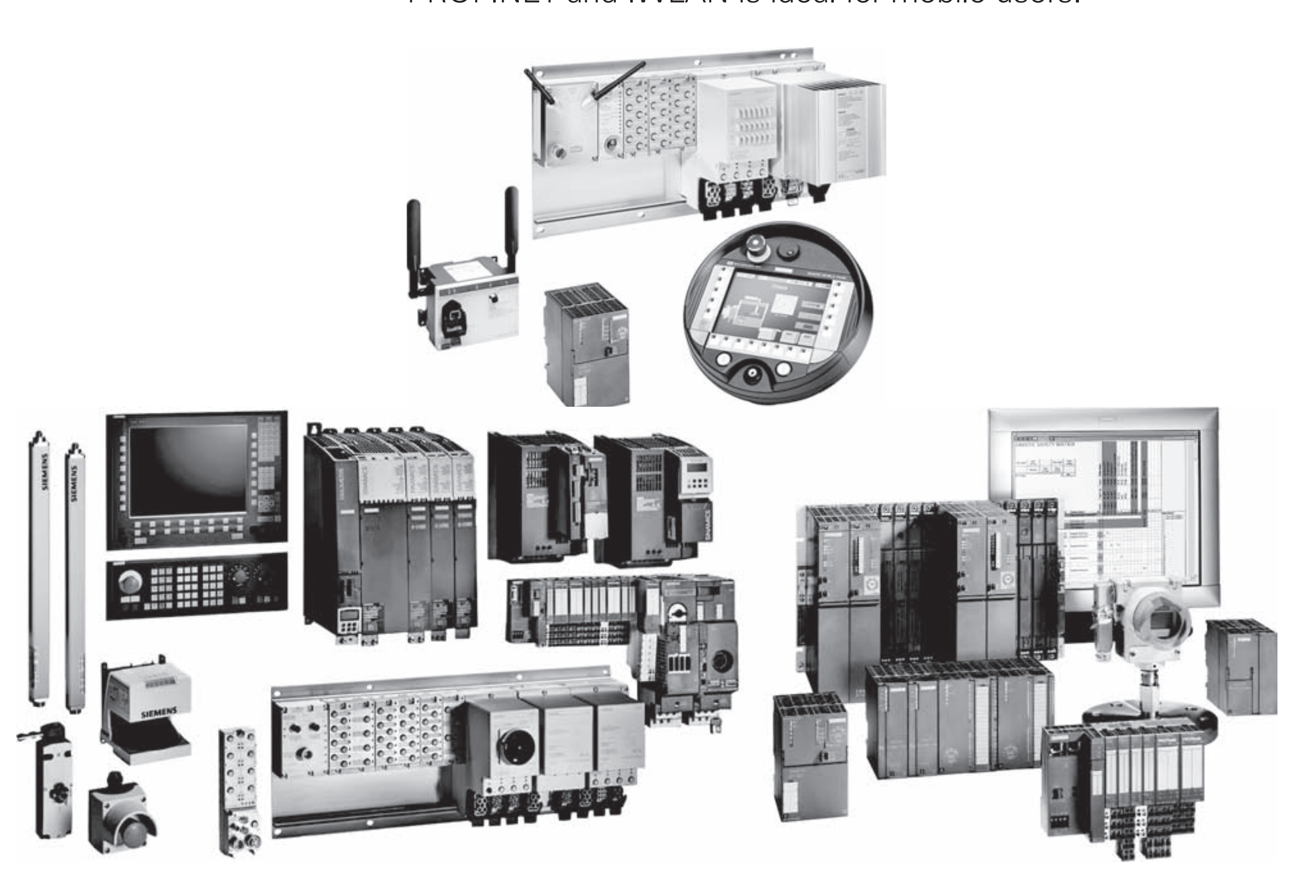


Basic ASIsafe Example

All This and More

In addition to the SIRIUS Safety Integrated products summarized in the previous pages, Siemens Safety Integrated products include a broad range of devices and systems for factory automation or process automation.

Multiple safety components can be interconnected using ASIsafe or networked with PROFIsafe. PROFIsafe enables fail-safe communication between sensors, safety control systems, and actuators via PROFIBUS and PROFINET. Data transparency at all levels ensures simplified commissioning, diagnostics and maintenance. Additionally, wireless fail-safe communication via PROFINET and IWLAN is ideal for mobile users.



Review 8

1. Siemens UL 1077 ________ are designed to trip faster than standard UL489 circuit breakers, providing additional protection for more sensitive devices.

2. Siemens terminal blocks are available with either ______ connections or ________ terminals.

3. A control relay's ________ number is the number of isolated circuits that can pass through the relay.

4. A control relay's ________ number is the number of closed contact positions per pole.

5. SIRIUS ________ solid-state relays, contactors, and function modules operate quietly and perform reliably at high switching frequencies.

6. A timing relay that receives a signal to turn on and then begins timing is referred to as an ________ timer.

7. SIRIUS ________ reduce machine and plant downtime by monitoring electrical and mechanical quantities and fault conditions and providing appropriate diagnostic indications.

8. ________ is a modular programmable relay system used to perform basic control tasks that are otherwise often handled using hard-wired control relays and other devices.

9. SIRIUS Safety Integrated system incudes ________ devices, ________ devices, and ________ devices and systems.

10. The safety-related design of AS-Interface was standardized for all manufacturers in the Safety at Work consortium and is marketed by Siemens under the copyrighted name ________.

Review Answers

Review 1

1) manually; 2) a. normally open contact, b. normally closed contact, c. coil; 3) a.

Review 2

1) left, right; 2) a. Node, b. Power Circuit, c. Power Load, d. Control Circuit, e. Control Device, f. Control Load.

Review 3

1) increases; 2) overcurrent; 3) overload; 4) low voltage; 5) SMF; 6) MMS and MRS; 7) motor starter protector; 8) contactors

Review 4

1) 10; 2) thermal, bimetal; 3) reset; 4) 3RU; 5) heaters, phase loss; 6) ESP200; 7) 3RB21, 3RB31; 8) IO-Link; 9) 3RR2; 10) SIMOCODE pro.

Review 5

1) motor starter; 2) NEMA, IEC; 3) 5; 4) 20; 5) 2; 6) separate winding and consequent pole; 7) Combination; 8) Wye-delta.

Review 6

1) S10, S12; 2) S00, S0; 3) AS-Interface, IO-Link; 4) 3RA6 compact starters; 5) M200D; 6) 3RW30, 3RW40, 3RW44; 7) PROFIBUS DP, AS-Interface 8) IO-Link

Review 7

1) Electrically held; 2) magnetically held, mechanically latched; 3) pilot; 4) 22; 5) blue, white, clear; 7) 50 mm, 70 mm; 8) integrated signal lamps.

Review 8

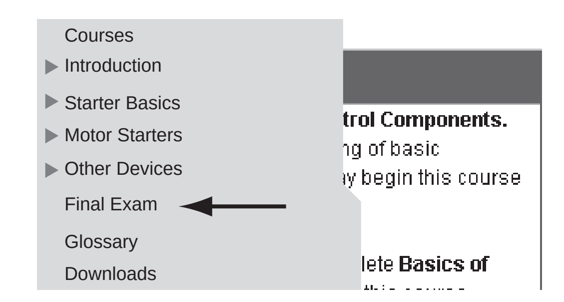
1) supplementary protectors; 2) screw, spring-loaded; 3) pole; 4) throw; 5) 3RF2; 6) on-delay; 7) monitoring relays; 8) LOGO!; 9) detecting, commanding and signaling, monitoring and controling; 10) ASIsafe.

Final Exam

Before taking the final exam, it is recommended that you delete the temporary internet files from your computer's web browser. For most versions of **Internet Explorer**, you can do this by selecting **Internet Options** from the **Tools** menu and then clicking on the **Delete Files** button. If you do not perform this step, you may see a score of 0% after you submit your exam for grading.

The final exam for this is course is available online at **http://www.usa.siemens.com/step**. This web page provides links to all our quickSTEP online courses. To complete the final exam for this course, click on the **Basics of Control Components** link.

Next, move your mouse over to the left so that the navigation bar pops out and select the **Final Exam** link. The final exam page will appear.



After you complete the final exam, click on the **Grade the Exam** button at the bottom of the page. Your score on the exam will be displayed along with the questions that you missed.

If you score 70% or better on the exam, you will be given two options for displaying and printing a certificate of completion. The **Print Certificate** option allows you to display and print the certificate without saving your score in our database and the **Save Score** option allows you to save your score and display and print your certificate. **The Save Score option is primarily intended for use by our distributors and Siemens employees.**